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From the global efforts on certification of bioenergy towards an integrated approach based on sustainable land use planning

J. van Dam *, M. Junginger, A.P.C. Faaij

Department of Science, Technology & Society, Copernicus Institute, Utrecht University, The Netherlands

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ABSTRACT

This paper presents an overview of 67 ongoing certification initiatives to safeguard the sustainability of bioenergy. Most recent initiatives are focused on the sustainability of liquid biofuels. Content-wise, most of these initiatives have mainly included environmental principles. Despite serious concerns in various parts of the world on the socio-economic impacts of bioenergy production, these are generally not included in existing bioenergy initiatives. At the same time, the overview shows a strong proliferation of standards. The overview shows that certification has the potential to influence direct, local impacts related to environmental and social effects of direct bioenergy production. Key recommendations to come to an efficient certification system include the need for further harmonization, availability of reliable data and linking indicators on a micro, meso and macro levels. Considering the multiple spatial scales, certification should be combined with additional measurements and tools on a regional, national and international level. The role of bioenergy production on indirect land use change (ILUC) is still very uncertain and current initiatives have rarely captured impacts from ILUC in their standards. Addressing unwanted LUC requires first of all sustainable land use production and good governance, regardless of the end-use of the product. It is therefore recommended to extend measures to mitigate impacts from LUC to other lands and feedstock.

Contents

* Corresponding author. Tel.: +31 30 877 00 47.
E-mail address: jinke@jvdconsultancy.com (J. van Dam).

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1. Introduction

The need to secure the sustainability and trade in a fast growing bioenergy market is widely acknowledged by various stakeholder groups. An earlier overview of developments in sustainable biomass certification from 2007 [1] shows the wide range of initiatives undertaken as steps towards the development of sustainability standards and biomass certification systems. In this paper, some urgent actions were identified as better international coordination between initiatives, building up experience on the ground and exchanging views on the WTO compatibility of a biomass certification standard. In addition, the possibility to use a set of policy tools, beside certification, to guarantee the sustainability of biomass production and use was emphasized. Since then, new initiatives have been developed to guarantee the sustainability of biomass and bioenergy, which can be added to an already long list of existing initiatives [1].

The aspect of food competition within the debate of sustainability of bioenergy emerged when food commodity prices increased sharply between 2004 and 2008: many analysts and commentators pinpointed the market development of biofuels as one of the main causes [2,3]. Others [4] stressed, however, that connections between rising prices and demand are highly complex and not per definition negative. Schubert et al. [4] indicates that higher food prices invariably impact on net consumers. Farmers that are net producers of food can, on the other hand, profit from the higher prices and increase their income, if other conditions remain unchanged.

Around the same time, the Searchinger paper [5] started a discussion on the impacts of Indirect Land Use Change (ILUC) from biofuel production on triggering higher crop prices, conversion of native lands and significant indirect GHG emissions. Succeeding reports and comments [6,7] indicated that these results were based on a narrow set of assumptions and pinpointed the complexity of land use changes on a global scale. In recent years, a wide range of additional reports [8–12] have discussed the topic, showing the importance to consider ILUC in bioenergy production and the complexity to find measures to monitor and minimize them.

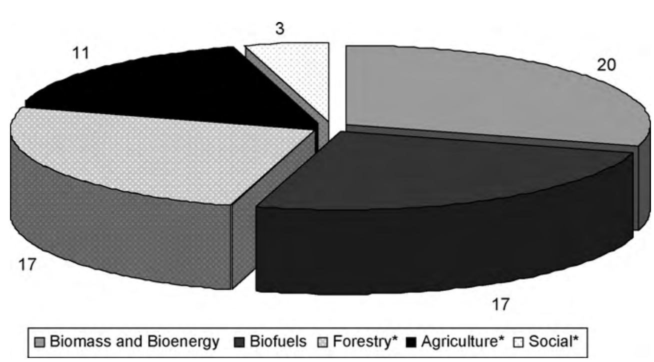

Fig. 1. Overview of amount of initiatives and certification systems included in review on biomass and bioenergy certification (*substantially more systems exist).

Initiatives and debates are thus ongoing on the further development of principles, criteria and verifiable indicators to safeguard the sustainability of biomass and bioenergy.

The objective of this paper is to provide a state-of-the-art overview of ongoing initiatives in biomass and bioenergy certification until the end of 2009 and, more importantly, to indicate the differences and similarities between these initiatives. The initiatives are compared by means of how sustainability principles are included. In addition, we analyze how these initiatives (plan to) verify and monitor the compliance of these sustainability principles, taking into account cost aspects. The analysis provides an overview of current bottlenecks, and required activities, to come to a harmonized, efficient system to guarantee the sustainability of biomass and bioenergy.

This paper describes in Section 2 an inventory of ongoing initiatives in the field of biomass and bioenergy certification, from the perspective of various stakeholder groups. The next sessions show similarities and differences between these initiatives by discussing how the sustainability principles (Section 3) and verification and monitoring aspects (Section 4) are included. Recommendations on how to move forward are given in the discussion and conclusions in Section 5.

2. Criteria development for biomass and bioenergy: an overview of ongoing initiatives

This section discusses the ongoing initiatives in the field of biomass and bioenergy certification, from the perspective of various stakeholder groups. First, we will discuss the general developments to develop sustainability principles in the recent years, followed by a discussion of the key initiatives for each stakeholder group.

Fig. 1 shows the number of initiatives and existing standards that are analyzed for this review. A background document [13] with detailed information on each initiative or standard is available at IEA Bioenergy Task 40[1] on request. Part of the review includes an analysis of existing standards on forestry, agriculture and social norms as their sustainability principles aim at sound resource management of bioenergy production. It must be noted that the standards included on forestry, agriculture and social norms is extensive but certainly not complete.

[1] This work is commissioned by IEA Task 40: http://www.bioenergytrade.org/.

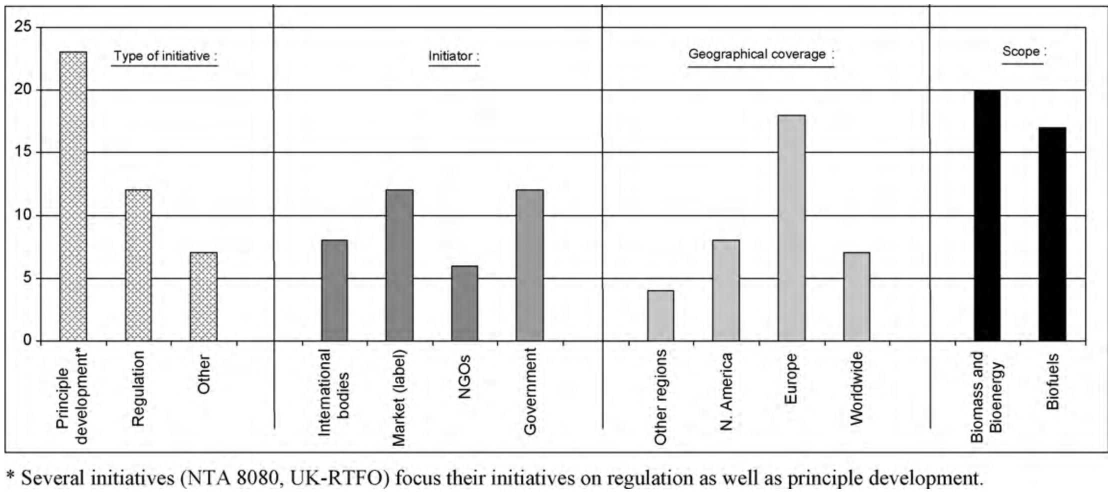

Fig. 2. Key characteristics of initiatives and systems on biomass and bioenergy certification included in overview. * Several initiatives (NTA 8080, UK-RTFO) focus their initiatives on regulation as well as principle development.

We have included 37 initiatives (including regulation) specifically aimed at the development of sustainability principles for biomass and bioenergy. Note that ongoing initiatives focused on the methodological development of a specific sustainability principle as ILUC are not included in this list. These initiatives will be mentioned in Section 3 under their relevant topic. Also, policy papers with key concerns for sustainable biomass and bioenergy that have not been further elaborated since the publication of Dam et al. [1], are not included in this review.

Fig. 2 shows the key characteristics of the initiatives specifically aimed at the development of sustainability principles for biomass and bioenergy. Main initiatives included originate from the European region, followed by the North American region. The relatively large share of initiatives aimed at biomass and bioenergy for heat and power (compared to liquid biofuels) can be partly explained by the inclusion of various green electricity labels that have included sustainability criteria (though limited and largely specified to resource demands) for biomass. The following subsections will give a short description of the initiatives included in Fig. 2 per stakeholder group.

2.1. National and supra-national policies

Many countries around the world have recently adopted policies that require, or strongly encourage, increases in the production and use of bioenergy – and in specific biofuels – over the next 5–10 years [14]. An overview of biofuel targets for selected countries is given by Peterson [15]. This overview limits itself to the countries and regions that have formulated sustainability requirements on the production and use of biomass and bioenergy in their policies.

2.1.1. Europe

The *European Commission* (EC) has set mandatory targets for an overall share of 20% renewable energy and a 10% share of renewable energy in transport in the EU's consumption in 2020, translated into individual targets for Member States (MS). Environmental criteria on GHG emission reductions, biodiversity conservation and good environmental management practices are developed and laid down in the Renewable Energy Directive (EC-RED) to guarantee the sustainability of biofuels and other bioliquids. Biofuels and other bioliquids that do not meet those criteria are not taken into account for the mandatory targets. It is expected that the sustainability criteria for biofuels and other bioliquids will go in implementation from 2011 onwards. Guidelines on reporting requirements are under development [16,17].

The requirement for a sustainability standard for solid biomass is under discussion at the EC [16]. The most recent Communication does not at this stage propose binding criteria at EU level, mentioning that MS that have, or who will introduce, national sustainability standards should ensure that these in almost all respects (exceptions are indicated) should be the same as laid down in the EC-RED [18]. The Benelux countries have reacted in a Communication that the absence of a Commission proposal in this regard is seen as a missed opportunity [19].

Various individual European MS are introducing sustainability standards on a national level. Individual MS are obliged to follow, where applicable, the European legislation. In the *Netherlands,* the developed sustainability criteria for biomass and bioenergy – the so-called 'Cramer Criteria' [20] – are translated into a national standard: NTA 8080 [21]. Its successor, NTA 8081, will include the European guidelines. Its criteria will be linked to the subsidies for electricity companies in 2010. The '*Corbey*' Commission (CBD), established in 2009, advises the government on sustainability issues of biomass and bioenergy. Recent recommendations include an advice on the implementation of the EC-RED reporting obligation, how to deal with ILUC and including sustainability criteria for solid biomass on European level [22].

In the *United Kingdom*, the *Renewable Transport Fuel Obligation* (RTFO) requires suppliers of fossil fuels to ensure that a specified percentage of the road fuels they supply in the UK are made up of renewable fuels. As well as obliging fuel suppliers to meet targets for the volumes of biofuels supplied (3.5% in 2010/11 of biofuel use by volume), the RTFO requires companies to submit reports on the carbon emission savings and sustainability of the biofuels [23]. The reporting standard is based on a 'meta-standard' approach under which existing voluntary agro-environment and social accountability standards have been benchmarked against the RTFO Meta-Standard. Transport fuel suppliers are allowed to report, at least initially, that they do not have information on the sustainability or otherwise of their biofuel [24].

In *Germany*, the Biomass Sustainability Ordinance for the Electricity Sector is designed to grant feed-in-tariffs for electricity production from liquid biomass on the basis of the EC-RED Directive requirements. It entered into force in 2009. The Biomass Sustainability Ordinance for Biofuels is designed along the same lines. It will implement the EC-RED Directive requirements covering raw materials cultivated inside or outside the territory

of the Community which are used for energy from biofuels and other bioliquids [25].

In *Switzerland*, biofuels are exempted (Biofuels Tax Exemption) from the mineral oil tax, provided their production complies with environmental and social criteria. Tax reduction for biofuels can be obtained if there is a 40% GWP reduction and a reduction of overall environmental impacts compared to the fossil reference system [26].

Belgium has committed itself to reduce its GHG emissions with 7.5% by 2012. In addition, electricity sales are submitted to a renewable obligation of 6% renewable electricity by 2010 in the frame of targeted green certificate systems. The system in Wallonia and in the Brussels region is based upon avoided CO_2 emissions with respect to a reference being a combined cycle power plant firing natural gas. No other environmental or social criteria are included [27,28].

2.1.2. North America

In the *USA*, the Renewable Fuel Standard (RFS) – included in the Energy Independence and Security Act (EISA) – provides provisions on the promotion of biofuels (especially cellulosic biofuels). EISA mandates minimum GHG reductions from renewable fuels, discourages use of food and feed crops as feedstock, permits use of cultivated land and discourages (indirect) land-use changes [29].

On a state level, *both Massachusetts and California* have developed legislation to ensure a certain sustainability level of biofuels. In 2009, Massachusetts has announced that waste-based biofuels are the only ones guaranteed to meet the state's renewable fuel standards. For other fuels, the state would not be making a decision until the EPA and California Air Resources Board agree on ways to analyze the GHG reductions (including ILUC) from such fuels [30]. In California, the Low Carbon Fuel Standard (LCFS) is a performance standard that is based on the total amount of carbon emitted per unit of fuel energy [31].

In *Canada*, a CEM Working Group on Renewable Fuels has a sustainability subgroup that has drafted Guiding Principles for sustainable biofuels produced in Canada. Beginning of 2010, a stakeholder consultation is in process. Furthermore, Canadian provinces are reviewing their sustainable forest management requirements to see if they are adequate to allow for increased removal of forest biomass for energy. Only one province (New Brunswick) has forest management guidelines for biomass removals for energy [32].

2.1.3. South America

In *Brazil,* the Social Fuel Seal forms part of the National Biodiesel program. It gives biodiesel producers incentives to source their raw materials from smallholders and family farmers. Tax breaks are determined by a set of criteria. One of them is the requirement that the biodiesel producer has to source raw materials from smallholders and family farmers. The Social Fuel Seal Program is joined (so far) by seven major Biodiesel producers. They are cooperating with more than 20,000 rural families registered in the standard and cover in total 1.5 million hectares [33].

2.1.4. Africa

The biofuels policy in *South Africa* is formulated, considering impacts of the sector on employment, food security and the ecosystem [34]. The focus of the Biofuels Industrial Strategy is on the promotion of farming in areas that were previously neglected by the Apartheid system and areas of the country that did not have market access for their products. The strategy recommends sugar cane and sugar beet for bioethanol production and soybeans, canola and sunflower as feedstock for biodiesel [35].

The biofuels policy framework of the *Mozambican government* focuses mainly on social-economic sustainability criteria, but environmental criteria are to be developed. The criteria[2] listed so far in the Biofuels Policy [36] include e.g. avoiding the use of basic food crops and income generation. The biofuels policy states that the government will select agro-ecological areas which are the only areas permitted for energy crop production. However, it is not stated what type of criteria will be applied.

2.1.5. Asia

The *Chinese* government has said that biofuels should not jeopardize food production. Current policies imply to discourage food crops in biofuels production but continue to provide production subsidies for ethanol from corn, wheat, and other crops [37].

The central government in *Indonesia* has established laws and regulations guiding biofuels expansion, including a ban on further forest destruction. Indonesia's Agricultural Ministry announced, however, in 2009 that it would lift the moratorium on palm oil plantations on peat lands. Indonesia considers Jatropha and coconut oil in its next phase of expansion in order to avoid competition with crude palm oil [37].

The *Japanese Government* has established a voluntary label, called the 'Biomass Mark', that can be obtained when a commodity originates totally or partly from biomass [38,39]. This is, however, not coupled to any sustainability requirement.

2.1.6. Australia–New Zealand

The *New Zealand government* has announced the introduction of a Biofuels Sales Obligation as part of a broader policy agenda. From 2008 onwards, companies importing petrol or diesel into New Zealand will be required to sell biofuels as a proportion of the energy content of their total annual sales. There is a provision in the Biofuel Bill to implement mandatory sustainability standards for biofuels [39].

Section 2.1 shows that recent government initiatives have their main focus on the development of sustainability criteria for biofuels, which excludes the production and use of solid biomass or bioenergy for heat and power. The consideration of socio-economic impacts of bioenergy production is generally of higher importance in developing countries while environmental principles are a key priority in Europe and North America. Avoiding competition of biofuel production with food is mutually recognized, though rarely translated into concrete policy measures (see also Section 4). See also Fig. 3.

2.2. International organizations

Various international organizations are developing sustainability principles for biomass and bioenergy. The *International Organization for Standardization* (*ISO*) intends to develop a standard specifically designed for the sustainability of bioenergy. Recommendations in 2009 to the Technical Management Board included the formal establishment of a new Project Committee with as scope the "Standardization in the field of sustainability criteria for production, supply chain and application of bioenergy". This Committee has to address in future work an inventory of initiatives, terminology, greenhouse gases, environmental and socio-economic aspects, verification and auditing and indirect effects [40].

Within Europe, the *European Committee for Standardization* (*CEN*) has established a Technical Committee (CEN TC 383) on 'Sustainably produced biomass for energy applications' to promote the standardization in the field of sustainable produced biomass [41]. Various working groups have been established [42]. It was

[2] List of criteria are based on the translation of the Mozambican biofuel policy by the Programme for Basic Energy and Conservation (ProBEC).

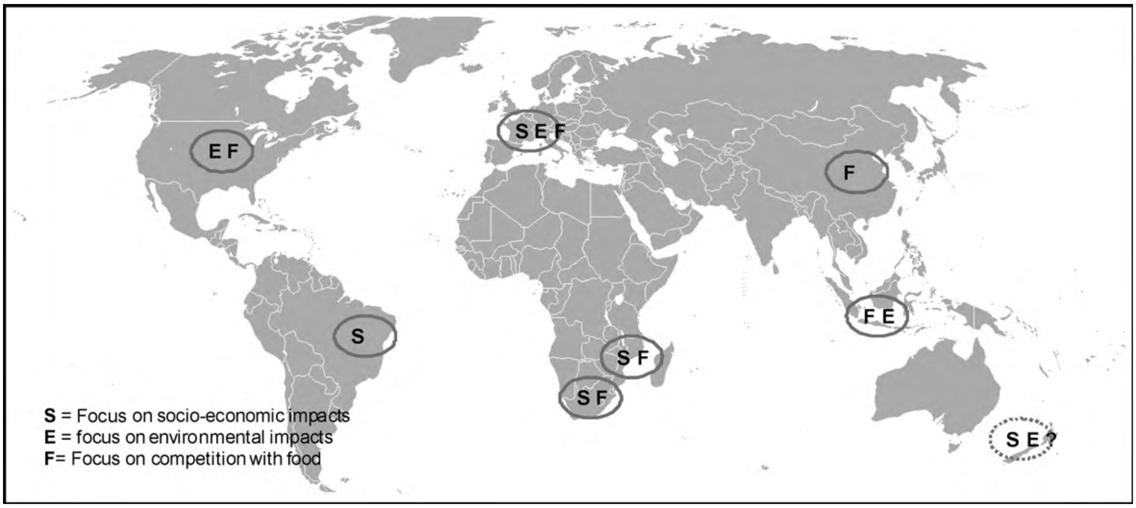

Fig. 3. Indication of key regions where governments (develop to) include sustainability principles for biomass and bioenergy in their policies and an indication of the type of principles to be included.

decided in 2009 that the CEN/TC 383 would in first instance focus on the principles that are also included in the EC-RED.[3] The working groups on socio-economic aspects and ILUC were set temporarily on hold and a decision on their further work will be made in 2010 [43].

The Global Bioenergy Partnership (*GBEP*) was launched in 2006. Partners of GBEP are both national and international organizations.[4] Its Task Force on Sustainability is developing a set of global science-based criteria and indicators (C&I), which are intended to guide any analysis undertaken of bioenergy at the national level to support decision making and to facilitate the sustainable development of bioenergy [44]. The Task Force aims to present its set of C&I during the G8 meeting in Toronto in 2010 [45].

The *Roundtable on Sustainable Biofuels* (RSB) is an international initiative bringing together multiple stakeholders concerned with ensuring the sustainability of biofuels production and processing. End of 2009, the RSB has released "Version One" of its Principles and Criteria, eligible for pilot testing [46]. The system is based on the idea of a 'meta-standard' system, which relies on existing certification and standards to assure that most RSB principles are met [47].

The *Inter-American Development Bank* (*IDB*) has created a Biofuels Sustainability Scorecard based on sustainability criteria of the RSB. The Scorecard has been designed to be used at multiple stages of project lifecycle and contains five environmental principles and one social principle [48].

Although not specifically developed for bioenergy, the *Global Reporting Initiative*[5] (GRI) has developed a general reporting framework on sustainability that includes indicator protocols on environmental and socio-economic issues [49]. Various other international organizations provide input to the discussion of sustainability of biomass and bioenergy through workshops, reports, etc. For example, *UN-Energy* published a report that provides a framework for decision-makers to consider nine key sustainability issues facing bioenergy development. Every principle is accompanied with various issues that need to be addressed in the local context [50]. The *United Nations Environmental Program* (UNEP) is hosting a series of issue papers to provide an overview of critical emerging topics (e.g. bioenergy, biodiversity and degraded lands) and to present options towards sustainable production and use of bioenergy [51,52].

2.3. Companies and associations

In recent years, companies and company associations have taken the initiative to develop (business-to-business) standards to guarantee the sustainability of bioenergy for fuel, heat and electricity.

2.3.1. Initiatives on sustainability of biomass and bioenergy for heat and electricity

Various national and international green electricity labeling standards have included principles in their standard to guarantee the sustainable production of biomass feedstock for electricity generation. Examples in North America are *Ecologo* (US, Canada) and *Green-E* [53,54]. Examples in Europe are *OK-Power* [55], *Milieukeur* [56], *Nature Made Star* and *Grüner Strom Label* [55]. *EUGENE* is the umbrella organization of green electricity labels in Europe [57]. Socio-economic and environmental demands are generally limited (with the exception of Ecologo) and restricted to demands on the biomass use in the installation (e.g. emissions) and on the origin of the feedstock.

In addition, various business-to-business standards are developed to guarantee the sustainability of biomass (resources) for electricity and heat generation. *Laborelec* and *SGS* developed the Laborelec certification system (LBE) in 2005 on behalf of the energy company *Electrabel*. The system is in use since 2006 [58]. Electrabel implements, amongst other sustainability principles, the energy and CO_2 balance of the supply chain including electricity use, fossil primary energy use and transport [58].

The company *DRAX* has established sustainability principles for biomass, until delivery at the end-user. The biomass is used for power generation in the UK. Its principles are based on the developing regulatory and policy initiatives of the UK, European Union and other markets [59].

The *Green Gold Label* (GGL) was an initiative of the energy company Essent. It aims at a traceable system for biomass from

[3] The use of standards is always voluntary. However, European standards are sometimes related to European legislation (Directives) and conformity to such standards may constitute a presumption of conformity to the legal requirements of the Directives. To support their legislation by written standards, the EC gives mandates to CEN.

[4] GBEP partners are: Brazil, Canada, China, Fiji Islands, France, Germany, Italy, Japan, Mexico, Netherlands, Russian Federation, Spain, Sudan, Sweden, Switzerland, Tanzania, United Kingdom, United States of America, FAO, IEA, UNCTAD, UN/DESA, UNDP, UNEP, UNIDO, UN Foundation, and World Council for Renewable Energy (WCRE) and European Biomass Industry Association (EUBIA). Various other countries and the World Bank are observers.

[5] GRI Reporting Framework is a general reporting approach to measure sustainability and therefore not included in the overview of initiatives on bioenergy certification.

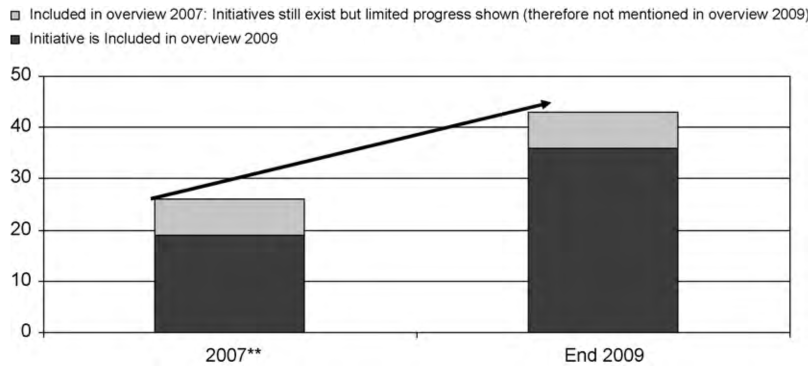

Fig. 4. Increase of initiatives to safeguard the sustainability of bioenergy since the last overview in 2007. ** Note that Dam et al. [1] describes in addition activities from stakeholders *related* to the development of sustainability principles of bioenergy. Examples are IEA Bioenergy Task 40, IEA Bioenergy Task 38 and various companies (Shell, Biox, and Rabobank). These initiatives are *not* included in the overview 2009 as they do not aim to develop sustainability criteria. Not included in this table are the Roundtables for agricultural Commodities.

(by-) products from the power plant (and its green power it produces) back to the sustainable source. The system is laid down in eight different GGL standards. At present 11 biomass suppliers have a certificate [60].

The *International Sustainability and Carbon Certification* (ISCC), coordinated by Méo Consulting, is an international certification system to guarantee the sustainability of bioenergy. ISCC includes 10 sustainability principles. The ISCC system is tried in a test phase, carried out in Europe, Latin America and in Asia [61]. The system is tentatively approved by the German government to check the sustainability of biofuels and other bioliquids [62].

2.3.2. Initiatives on sustainability of biofuels

The company *Greenergy* has developed a standard to guarantee the sustainability of its bioethanol supply from Brazil (including sugarcane production and processing) to be used for bioethanol in the UK. The Greenergy interpretation for Brazilian sugarcane is an adaptation of the RTFO sustainable meta-standard for biofuels, specifically for the Brazilian ethanol context [63]. Remarkably comparable with the previous initiative: the company *SEKAB* has developed seven criteria for sustainable ethanol, produced in Brazil (Sao Paulo State) with Sweden as destination country [64].

ENERS Consulting Company, together with other project partners, aims to set up a label for fuel-bioethanol (etha STAR) and fuel-biodiesel (fame STAR) for use in the EU and the Swiss vehicle fuel market. Included are requirements on the socio-economic, environmental and technical performance [65].

The *National Biodiesel Board* (USA), the national trade association of the biodiesel industry, has developed a set of sustainability principles [66]. The principles, based on existing initiatives, are seen as a set of ideal goals for the entire industry. NBB mentions specifically that they are not intended to supplant other efforts related to biodiesel sustainability certification or to suggest support for any certification system [67]. The principles are not yet further developed into criteria.

2.4. NGOs and independent associations

Several NGOs have expressed their viewpoints on sustainable bioenergy production and various of them, published before October 2007, have been mentioned in Dam et al. [1]. This overview discusses (new) NGO initiatives or activities since that time, focused on (further) development of principles to guarantee the sustainability of bioenergy. This section also includes initiatives from independent projects or associations.

NGO initiatives included in this overview largely come from the European and US region. In Europe, the *CO_2Star Campaign*, part of the EC-funded Carbon Labeling project, was formed as non-profit initiative in 2006. A label for biodiesel was developed (CO_2Star) was developed within the project, in cooperation with the German fuel retailer Q1, indicating CO_2 reductions of biodiesel from rapeseed versus diesel [39].

The *Nordic Ecolabel* (also called the *SWAN*) is the official ecolabel for the Nordic countries[6] in Europe. Criteria are developed for fuels and for biofuel pellets, amongst 66 other product groups. Criteria for biofuel pellets include requirements on manufacturing methods, transportation and storage. Sustainability criteria are developed for fuels that have at least 33% of renewable raw materials [68,69].

In the North American region, *The Sustainable Biodiesel Alliance* (SBA) aims to promote sustainable biodiesel practices in the USA – just as NBB – including the harvesting, production and distribution of biodiesel fuels. Four working groups have developed draft principles and baseline practices for biodiesel production and distribution, which were open for public feedback in August 2008 and ratified in September 2008 [70].

The *Council on Sustainable Biomass Production* (CSBP), initiated in North America, is a multi-stakeholder initiative developing biomass to biofuel sustainability principles for the production of feedstock for 2nd generation cellulosic refineries [71]. In 2007, a first meeting was organized to establish and adopt its vision, objectives, and timeline. This multi-stakeholder process is ongoing [71].

Worldwide, the NGO *World Wildlife Fund* (*WWF*) [72] has published a position paper in 2008, which outlines the key issues and principles that should be addressed to guarantee the sustainability of bioenergy. WWF supports e.g. a global "roundtable" approach, involving relevant stakeholders, as a way of agreeing on a system for assuring acceptable performance of bioenergy. Also, governments should ensure adherence to international efforts towards making bioenergy sustainable, as well as support compliance by private sector players to these standards.

In addition, various NGOs have published reports, commenting on ongoing initiatives to develop sustainability criteria for bioenergy. Examples are FASE-ES [1] or the NGO *Corporate Europe Observatory* (CEO). The latter has published a report in which it questions the effectiveness of certification systems to guarantee the sustainability of bioenergy systems [73]. Fig. 4 shows, as final conclusion for this session, the strong increase in initiatives to safeguard the sustainability of bioenergy since the last published overview in 2007 from Dam et al. [1].

[6] Members of the eco-labeling scheme are Norway, Sweden, Finland, Iceland and Denmark.

3. Meta-standard approach: sustainability standards for feedstock

Biomass can be produced in agriculture or in forestry (plantations) as dedicated product or as residue. Different certification systems already exist for the forestry and agricultural sector to ensure environmental benign or sustainable production methods that provide safer or healthier products to the consumer [74].

Various initiatives to guarantee the sustainability of bioenergy (e.g. UK-RTFO, NTA 8080) make use of a meta-standard approach. The rationale behind this approach for sustainably managed natural resources is given by the variety of already-existing standards, covering sustainable agriculture, forestry and social conditions. Such a meta-standard serves as benchmark standard. Instead of requiring producers to get certification for the meta-standard directly, compliance with the meta-standard is achieved through existing standards. These need to proof that they sufficiently guarantee that (most of) the principles and criteria of the meta-standard are complied with. A consequence of using a meta-standard approach is that national and regional policies rely partly on voluntary certification standards for agriculture and forestry to meet project-scale sustainability initiatives [75]. In this section, we will give a summarized overview of existing social standards and standards for agriculture and forestry.

3.1. Forestry standards

The most known forestry standards to be applied on a project level are the *Forest Stewardship Council* (FSC) and the *Program for Endorsement of Forestry Certifications* (PEFC). FSC is an international, stakeholder owned system for promoting responsible management of the world's forests. FSC certificates exist for Chain of Custody (CoC), forest management and controlled wood. Over the past 13 years, over 90 million hectares in more than 70 countries have been FSC certified [39,76].

PEFC is a global umbrella organization for the assessment of and mutual recognition of national forest certification schemes developed in a multi-stakeholder process. PEFC includes 35 independent national forest certification systems [77]. Examples are: CERFLOR (Brazil), CSA Canada, CERTFOR Chile or the Malaysian Timber Certification Council (MTCC) [77]. Several of the recognized PEFC systems are criticized by (mainly) NGOs because of limited stakeholder participation or low standards for sustainability [78,79].

PEFC plays – in contrary of FSC – no role in the development of international forestry principles, and relies instead on intergovernmental principles developed and adapted for different regions of the world. Examples are the *Pan European Principles for European Forests* or the *ATO/ITTO* principles [80]. The *Ministerial Conference on the Protection of Forests in Europe* is a governmental initiative in Europe that developed national criteria for Sustainable Forest Management for monitoring and reporting [81].

The purpose of the C&I from the *International Tropical Timber Organization* (ITTO) is to provide member countries with a tool for monitoring and reporting changes in forest conditions and management systems at national and forest management unit level. The *African Timber Organization* (ATO) developed similar C&I for the sustainable management of African natural tropical forests [82,83].

Related to the forestry standards mentioned above, are the so-called climate standards. As example, the *Climate, Community and Biodiversity Standard* (CCBS) defines rules for LULUCF/biosequestration projects that specifically focus on maximizing biodiversity and social benefits. CCBS focuses on various project types. Examples are reforestation, agro-forestry plantations and enrichment planting [84].

3.2. Agricultural standards

Various agricultural standards exist that were primarily developed for health and safety or for the development of sustainable farming practices (e.g. organic farming). In recent years, various Roundtable initiatives (see Section 3.2.2) have been established with the vision to make commodity chains more sustainable. Several of these commodities (e.g. sugar cane, palm oil, and soybean) can also be used as feedstock for the production of first generation biofuels.

3.2.1. Sustainable farming practices

The list of existing agricultural standards that focus on sustainable farming practices is immense and only a selection of them is discussed in this paper. The *International Federation of Organic Agriculture Movements* (IFOAM) is the worldwide umbrella organization for organic organizations. IFOAM is a Meta-Standard by itself and focuses on accrediting other standards for organic agriculture based on a set of general criteria. Currently, IFOAM has accredited 33 organic standards over the world for a variety of crops [39], see also [85]. IFOAM is one of the members of the advisory committee of the EC on organic agriculture.

The European Council of Agricultural Ministers adopted *Regulation* (*EEC*) *No. 2092/91* on organic farming and the corresponding labeling of agricultural products and foods. All products that bear the EU organic logo have been produced in accordance with the EU Regulation on organic farming. Various national European labels on organic agriculture require the fulfillment of the 2092/91 criteria [86].

The *Sustainable Agriculture Network*/Rainforest Alliance (SAN) is a coalition of non-profit, independent conservationist organizations, promoting the social and environmental sustainability of agricultural activities [39]. Certified crops include e.g. soy, sugarcane, sunflower, palm oil or coffee. SAN has released a document with additional criteria for oil palm, sugar cane, soy, peanut and sunflower farms in 2009 [87].

GlobalGAP is a private sector body that sets voluntary standards for the certification of agricultural products worldwide. GlobalGAP is a pre-farm-gate-standard: the certificate covers the process of the certified product from before the seed is planted until it leaves the farm. Other standards are recognized to cover the remaining parts of the process chain. Standards are available for a broad range of crops including soy, palm oil, sugar cane, rapeseed, sugar beet, wheat, corn and maize [39]. There is an umbrella standard on integrated farm assurance, combined with crop-specific standards [52].

The *Fair-Trade Labelling Organisations International* (*FLO*) has developed a standard to secure fair trade for producers from, especially, developing countries [88]. Generic product standards include a set of environmental, socio-economic, social and labour principles. Generic trade standards include principles as minimum price requirements and traceability. Standards are available for various agricultural products as sugar, coffee and oilseeds [89,90].

Agricultural standards that are recognized so far (more can be included over time) by UK-RTFO are: *Combinable Crops Standard* (ACCS), *Basel criteria for soy* (Basel), *Genesis Quality Assurance* (QA) and *Linking Environment and Farming Marque* (LEAF). More information about existing agricultural standards can be found in the membership list from IFOAM [91] and in the Ökolandbouw database [92].

3.2.2. Roundtable initiatives

Commodity roundtables are multi-stakeholder initiatives with the objective to make the commodity value chain more sustainable. Examples are the *Roundtable on Sustainable Palm Oil* (RSPO),

the *Roundtable on Responsible Soy* (RTRS) or the *Better Sugarcane Initiative* (BSI).

The *RSPO* principles and criteria are currently translated into national interpretations for Indonesia, Malaysia, Colombia and Papua New Guinea [93]. It was decided end of 2009 to delay the inclusion of GHG criteria for industry until a standard methodology is agreed upon [94,95].

The version for the field tests of the *RTRS* P&C was approved in May 2009. As next step, soy producers of various sizes and from various countries are testing the P&C and comment on their findings. End of 2009, soy producing countries (e.g. Argentina) are developing national interpretations of the P&C which will become, after endorsement by the RTRS, the basis of certification in that country [96,97].

BSI published its second standard on P&C in November 2009 after an extensive consultation round [98]. The second phase for public consultation was ended in January 2010. As next step, various stakeholder outreach meetings are planned in various regions in the world [99].

3.3. Sustainability standards for social conditions

Various standards are developed to safeguard social conditions. ISO has established a Working Group in 2005 to develop an International Standard providing guidelines for social responsibility. The guidance standard will be published in 2010 as 'ISO 26000' and be voluntary to use. It will not include requirements and will thus not be a certification standard. The work is intended to add value to, and not replace, existing inter-governmental agreements with relevance to social responsibility [100].

The *Standard on Social Accountability International SA8000* is an auditable certification standard for improving working conditions, based on international workplace norms of ILO conventions, the Universal Declaration of Human Rights and the UN Convention on the Rights of the Child [39].

The ETI Base code is another standard specifically developed to safeguard labour conditions. The governing board is represented by companies (e.g. Body Shop, Chiquita Brands), trade union organizations and NGOs. The code is based on national law and internationally agreed ILO labour standards [55].

3.4. Final remarks on overview existing standards

The previous sections provided an overview of the overwhelming amount of standards (in development) that are applicable to safeguard the sustainable production and use of bioenergy and its feedstock. Fig. 4 shows the strong increase in initiatives to safeguard the sustainability of bioenergy since 2007 [1].

As was previously recommended by various authors [1], a proliferation of standards, differing from one country or region to another, has to be avoided because of a risk for "shopping" between standards, market distortion and a decrease in credibility. Further coherence in biomass certification systems, possibly through promotion of international agreements and standardization, is therefore highly needed.

This coherence in systems is partly limited because of differences in priority between systems: Energy security and combating climate change (reducing GHG emissions) have been the main drivers to develop sustainability principles and standards for bioenergy [101]. In contrast, standards as IFOAM and Global-GAP were primarily developed for health and safety. Due to these differences in priority, the sustainability principles in agricultural and forestry standards cannot (all) be used to replace the sustainability issues that are stipulated by bioenergy standards (under development). This will be further discussed in Section 4.

A meta-standard approach, in combination with using international agreements, could partly solve the proliferation and priority differences of standards. This approach has also been successfully applied in agricultural and forestry standards (see Section 3) and by ongoing bioenergy initiatives as UK-RTFO and RSB. A key set of sustainability criteria, possibly extended with sector-specific sustainability criteria, should be embedded in a meta-standard for the forestry, agriculture and bioenergy sector (see Fig. 5). Existing meta-standards (IFOAM, PEFC, and RSB) could take the lead in this harmonization process.

4. Sustainability principles: included in standards and how?

In a standard, principles are translated into criteria, which describe the likely or achieved short term and medium term effects of interventions' outputs. Process indicators (variable that measures resources applied to a project) or result indicators measure whether a criterion is complied with [102].

In this section, we will discuss how initiatives aim to guarantee sustainability of bioenergy production by comparing proposed principles, C&I of key socio-economic and environmental issues. Initiatives included in each section are a selection of main initiatives for bioenergy certification (EC-RED, US-RFS, NTA8080, UK RTFO, RSB, RTRS, RSPO, BSI and ISCC) which are selected because of their (i) broader recognition [55,80] or (ii) their further elaboration of C&I compared to other initiatives.[7] The overview is completed with initiatives that provide relevant insights for the specific topic. In each section, similarities and mutual differences are discussed followed by a short conclusion and recommendations for further improvement. As coherence in systems is highly needed (see Section 3.4), recommendations include required activities for further harmonization in methodologies and data need.

4.1. GHG balance and carbon stock changes

As reducing GHG emissions is a prominent goal for bioenergy policies, various initiatives have developed principles that require levels of GHG reductions based on a Life Cycle Assessment (LCA) of production processes. Table 1 shows that some of these principles require process improvements over time (RSPO, RTRS, and SAN) while others require a specific target to be achieved (BSI, EC-RED, and SEKAB).

Required GHG reduction levels compared to the fossil fuel range from 20% (US-RFS, conventional biofuel) to 85% (SEKAB) and all in between, depending on the geographical region and feedstock type. Typically, required reductions are higher for electricity than for biofuels. The heterogeneity in GHG emission reduction requirements may promote "shopping" between initiatives and standards by producers and end-users.

Various initiatives (EC, Netherlands, UK, SWAN, RSB, BSI and others) propose or are developing methodologies and default values to calculate the GHG emission (reduction) for bioenergy chains [16,69,98,103–107], see also Table 2. These ongoing developments are complementary to already existing GHG tools (e.g. CO2Fix model, TimberCam, CAMFor and the HWP model), databases (e.g. SimaPro, Ecoinvent, KCLEco, GREET model) and international protocols as developed within the framework of UNFCCC [108]. In addition, there are several initiatives (e.g. Greenhouse Gas Protocol Initiative, GBEP) to promote the harmonization of methodologies to calculate GHG emission reductions [106,109].

The differences in approaches between various initiatives (see Table 2) show the difficulty in achieving a unified and interna-

[7] The complete overview of initiatives, and an overview of proposed principles and C&I, is available on request.

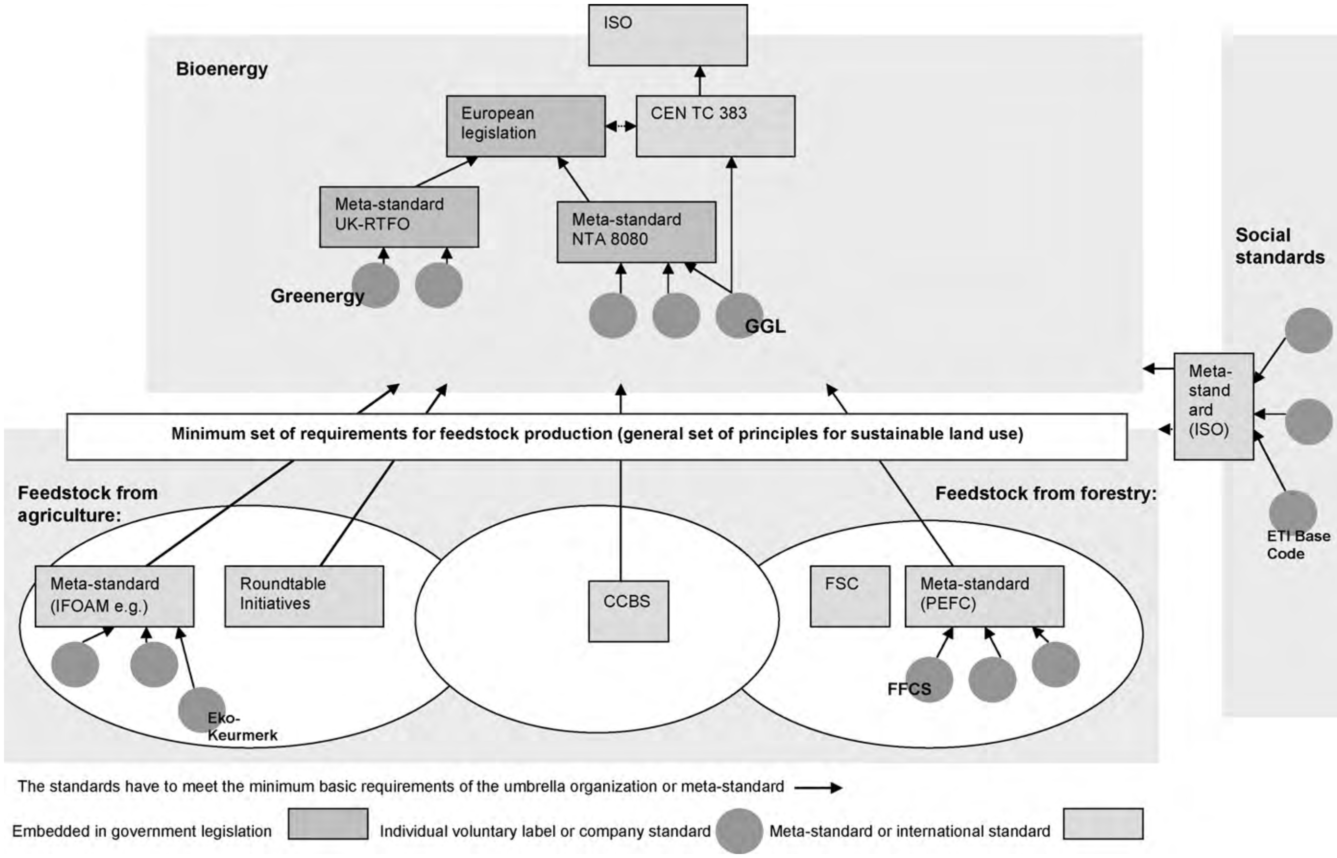

Fig. 5. Recommended approach to come to a harmonized system to guarantee sustainability of bioenergy and its feedstock.

tionally accepted methodology as well as default values. This difference is also demonstrated by the following example: typical GHG reduction values for soy-based biodiesel range from 31 to 40%, according to JRC [110], to 57–85% according to US-RFS [111]. Some harmonization efforts can be observed as well though: BSI Version 2 has adapted its GHG methodology to meet the EC-RED requirements [98].

Within the debate, discussions on how to calculate and prevent emissions from direct and indirect (see Section 4.6) land use changes (LUC) are ongoing. Various initiatives (e.g. EC-RED, US-RFS, NTA 8080) attempt to safeguard GHG gains by barring bioenergy on some newly converted lands with high carbon stock levels. US-RFS contains tougher criteria than the proposed EC-RED (see also Section 4.2). EC-RED has created a disincentive, though, by accounting for emissions from direct LUC amortized over 20 years, with specific emissions specified for different potential types of land conversion [98]. Note that the outcomes of the GHG performance from European and US regulation may have consequences for specific crop-region combinations. This may lead to objections from biomass producing countries as is shown by the plan of some palm oil producers to file a WTO case against the EU Palm Oil Directive [112].

It should be mentioned that carbon emissions from LUC, although often calculated with default values, are site specific. Searchinger et al. [5] assumes for example that conversion of forest to the biofuel crop results in a 25% loss of soil carbon in the top meter of the soil. Veldkamp et al. [113] mentions that this is a reasonable average but one that may vary substantially among sites, crops and production practices, and does not account for turnover of deeper carbon that can augment or offset differences in the upper soil.

The nuances and variability of GHG balances, due to the complexity of biomass energy systems and the sensitivity of the results for a wide range of parameters and factors, is illustrated by various other authors as well [101,114,115]. Possible solutions to come to a unified methodology are discussed in Dam et al. [101]. Key conclusion: there is a need for reaching international agreement on both a detailed methodology and the (default) data used for the calculations.

4.2. Biodiversity

Maintenance of biodiversity is relevant on various spatial scales and both short and long-term effects must be taken into consideration. Biodiversity is generally recognized as a key principle to include in a sustainability standard for bioenergy. Standards differ, however, strongly, in their set of proposed C&I. Generally speaking, standards follow two opposite approaches, or an approach in between them:

a. Assuming that feedstock production may harm biodiversity. This is prevented by the exclusion of lands with a certain degree of biodiversity;
b. Assuming that feedstock production may enhance (under certain conditions) the biodiversity of a region. Feedstock production must promote or restore biodiversity;
c. Follow an approach in between A and B..

Approach A is followed for example by EC-RED and the SWAN label. The latter mentioning that “the raw material does not originate in areas in which biodiversity or values worthy of protection for social reasons are under threat” [69]. Naturland

Table 1
Proposal GHG emission reduction requirements for selected initiatives.

Initiative	Proposed GHG reduction requirement	Ref.
EC-RED	At least 35% GHG emission reduction compared to reference fuel Rising to 50% on January 2017 to 60% in 2018 for biofuels and bioliquids produced in installations in which production started on or after January 2017	[16]
US-RFS	Conventional biofuels: 20% lifecycle GHG threshold (below gasoline) Advanced biofuels: 50% lifecycle GHG threshold Biomass-based diesel: 50% lifecycle GHG threshold[a] Cellulosic biofuel: 60% lifecycle GHG threshold	[143]
NTA 8080	For electricity and heat at least 70% in case of reference of Dutch mixture of electricity or coal, or at least 50% in case of reference of natural gas If in the chain of biomass innovative preparation technology or technologies are demonstrably used to enlarge the availability and/or applicability of sustainable biomass, a minimum of 50% applies For transportation fuels at least 50%; for those flows of biomass for which in the EC-RED "a typical GHG emission saving of less than 50% is included as transition period till 2012, a minimum of 35%	[21]
UK-RTFO	Targets to overall level of GHG saving achieved by the biofuel supplied in each obligation period: 2008–2009, 40%, 2009–2010, 45%, 2010–2011, 50%, etc. The level of GHG saving is an overall target for all fuels and feedstock reported by a fuel supplier Will follow the EC-RED Directive	[23]
RSB	Biofuel shall have lower GHG emissions than the fossil fuel baseline and shall contribute to the minimization of overall GHG emissions. The threshold (10, 40 and 70% is under discussion) will be set at the conclusion of the test period	[46]
RTRS	Efforts to reduce emissions of Greenhouse gases are made	[96]
RSPO	Plans to reduce pollution and emissions, incl. greenhouse gases, are developed, implemented and monitored. GHG criterion is voluntary element (under discussion).	[95,118]
BSI	Total $<0.4\,t\,CO_2$ equiv./t sugar (field-to-gate emissions) Total $<29\,g\,CO_2$ equiv./MJ (only used if ethanol is produced)	[99]
ISCC	Development, implementation and monitoring of plans to reduce GHG emissions; minimum savings rate in GHG emissions over the complete supply chain	[61]
SEKAB	At least 85% reduction in fossil carbon dioxide compared with petrol, from a well to wheel perspective	[64]
SWAN (fuels)	Over the course of the life cycle, emissions of greenhouse gases must not exceed 50 g of CO_2 equivalents/MJ of fuel	[69]
DRAX	Significantly reduce GHG emissions compared with coal-fired generation and give preference to biomass sources that maximize this benefit. Drax strives to reduce GHG emissions by at least 70% in comparison to coal-fired generation	[59]
SAN	The farm must implement practices to diminish its emissions of GHG gases and increase CO_2 sequestration. Practices include, e.g. soil cover management, using clean technologies, improving energy efficiency aimed at GHG reduction and CO_2 sequestration	[87,117]

[a] 20–50% still counts as renewable fuel.

Table 2
Methodological choices initiatives to calculate the GHG balance[a] [16,61,69,98,103,104,107,170,171]. • = included, X = not included and ? Uncertain.

Initiative	Functional unit	Scope	Allocation	Default values	ILUC	LUC	Selected time period
EC-RED	$g\,CO_2$ eq/MJ	Biofuels and bioliquids	Based on energy content	Typical and default values	X	•	Annualized emissions based on 20 years
US-RFS	GHG reduction (%) compared to fossil fuel	Renewable fuels	Displacement method [172]	Results provided by EPA to producer	•	•	100 year with 2% discount rate OR 30 year with 0% discount rate
NTA 8080	$g\,CO_2$ equiv./km $g\,CO_2$ equiv./MJ	Biofuels, bioenergy for heat and power	Based on energy content	Conservative, typical and best practice	X	•	Annualized emissions based on 20 years
UK RTFO	$g\,CO_2$ equiv./MJ	Biofuels	Substitution approach preferred	Conservative	X	•	No direct land use change with a carbon payback time exceeding 10 years
RSB	$g\,CO_2$ equiv./MJ	Biofuels	Guidelines under development	Criteria for acceptable default values under development	?	•	Based on IPCC methodology
BSI	$t\,CO_2$ equiv./t sugar (field-to-gate) or $g\,CO_2$ equiv./MJ (for ethanol)	Growing and processing of sugarcane to ethanol or sugar	Based on energy content, price or mass[c]	Guidance provided in document with set of default values	X	•	Annualized emissions based on 20 years
ISCC[b]	$g\,CO_2$ equiv./MJ	Biofuels and bioliquids	Based on energy content	Typical and default values	X	•	Annualized emissions based on 20 years
SWAN	$g\,CO_2$ equiv./MJ	Biofuels	Substitution approach preferred	Provided (not for production)	X	•	Not specifically defined

[a] The RSPO and RTRS have not (yet) developed a GHG methodology or protocol and are therefore not included in this table.
[b] Based on EU methodological framework.
[c] Allocation based on energy content recommended when end-product is used for energy. Allocation based on price recommended when end-product is used for sugar. In case of equivalent quantities of sugar and ethanol production, allocation based on mass is suggested as alternative.

Table 3
Biodiversity topics included in selected initiatives [16,21,46,63,96,98,105,118,125,143,173–175]. • = Included, – = not included.

	EC-RED	US-RFS	NTA8080	UK-RTFO	RSB	RSPO	RTRS	BSI	ISCC	Greenergy	CERFLOR	SFI	GGLS2	SAN
Primary forests specifically mentioned	•	–	–	–	–	•	–	–	•	–	–	•	•	•
Biodiverse grassland specifically mentioned	•	–	•	•	•[a]	–	–	•	•	•	–	–	–[b]	•
New plantings specifically mentioned	• (2008)	•[c] (2007)	• (2007)	• (2005)	• (2009)	• (2005)	• (2008?)	• (2008)	• (2008)	• (2005)	–	–	–[b]	• (2005)
Nature protected areas by relevant authority (national level)	•	–	•	•	•	•	•	•	•	•	•	•	•	•
Protected areas recognized by international agreements (Ramsar, Kyoto, CBD)	–[d]	–	•	•	•	•	–	•	–	•	•	•	–[a]	–[d]
Protected areas in lists drawn up by IUCN	–[d]	–	•	•	•	•	–	–	–	•	–	–	–[a]	–[e]
Protected areas defined by stakeholder process	–	–	–	•	•	•	•	•	–	•	–	•	–[a]	•[f]
Additional criteria	–	–	•	–	•	•	–	•	–	–	•	•	•	•

[a] Definition provided in guidelines for natural grasslands.
[b] GGL recognizes other agricultural standards that may include information on this topic.
[c] Existing cropland criterion: renewable fuel must be produced from renewable biomass harvested from land "cleared or cultivated" prior to enactment of EISA.
[d] Not specifically mentioned.
[e] References made to international conventions in definition list and sources.
[f] Local interpretation is included for defining natural ecosystems.

(standard on organic farming) follows approach B, mentioning that "The farmer is obliged to conserve and, if required, to recreate structural elements of the landscape. This . . ..serves the promotion of beneficial organisms and self-regulation of the ecosystem"[116].

Various standards as SAN [87,117], RTRS [96] and RSPO [118] adopt a middle course and differentiate their criteria for existing sites, where biodiversity has to be conserved or restored, and for new sites, where certain areas with biodiversity are excluded. NTA8080 makes the following distinction: Biodiversity criteria for (a) new or recent developments, for (b) maintenance and recovery of biodiversity and for (c) strengthening of biodiversity [21]. Table 3 shows that various standards, especially the ones focused (partly) on bioenergy production, place specific conditions on where to grow new plantings. There are differentiations in the selected reference year, varying from 2005 (RSPO, SAN, Greenergy) to 2009 (RSB).

There are different visions between standards on which areas should be protected because of their biodiversity. Initiatives as UK-RTFO and NTA8080 require that bioenergy production is avoided in areas with a high biodiversity, which is defined by the classification of biodiversity by six conservation values. EC-RED focuses on relatively pristine habitats precluding direct conversion of forests either 'undisturbed or re-grown to natural species composition', legally protected areas and highly biodiverse grassland. It also prohibits conversion of wetlands to non-wetlands and forests to other uses. US-RFS prohibits any new clearing of natural areas for biofuel production by limiting the direct sources of biofuel feedstock to existing actively managed or fallow agricultural lands and privately owned tree plantations, as well as waste and residues. It also prohibits plowing up natural grasslands [119].

Standards use different approaches on how to categorize or select areas with high biodiversity. There is in general agreement that the recognition of national laws and regulations on biodiversity should be included as criterion, which means e.g. that national protected areas are recognized. Note that the level of protection and compliance to protect these areas may differ from country to country. For this reason, additional approaches are developed to point out biodiversity-rich areas.

Various standards, as RSB, follow the approach that High Conservation Value (HCV) areas are defined in a participatory process (on a national or regional level). These national assessments are already available for some countries. HCV areas are defined as "natural habitats where inherent conservation values are considered to be of outstanding significance or critical importance" [120]. HCVs are interpreted in a stakeholder context leading to a certain *subjectivity* of the defined high HCV areas. These may, as a result, differ per country or per region depending on the stakeholder's priorities. To avoid this subjectivity, various standards apply (instead or in addition) strict definitions to locate biodiversity-rich areas. RSPO [118] provides for example a definition on primary forest (based on FAO) while the EC provides a strict definition on 'continuously forested area' [16]. Areas that comply with this definition are labeled as biodiverse, forest or grassland area.

Definitions, already developed by mature standards, may serve as guidance to define areas with a certain biodiversity level for exclusion, biodiversity conservation or restoration. In other cases, as with SAN [117], definitions match with the ones applied in international conventions as the Convention on Biological Diversity (CBD). Other standards refer in their guidelines explicitly to international organizations or to international agreements for defining or categorizing biodiverse areas, which has as advantage that identification approaches and databases are often already developed.

Note that the main focus of existing definitions and databases is on the protection of biodiversity and no to limited attention is given on how to determine the possible impact of bioenergy (positive and negative) on (agro-) biodiversity. Kuijk et al. [121] shows the difficulty of providing a clear answer on the contribution of forest certification on biodiversity. In most cases, the required systematic collection of information does not take place. Data from non-certified forests, which are needed to assess the added value of certification, are even harder to find. This gap in data need and methodological approach is also mentioned by Dam et al. [114] and in the WAB assessment [122].

Examples of international databases are shown in Table 4. The IBAT tool merges several of these databases into one tool. Although international databases seem to provide a coherent starting point to point out biodiversity-rich areas, there are also limitations. Some of the databases in Table 4 are developed by NGOs, which means that the indicated areas may not be officially recognized by legislation. Also, various databases may be outdated. An example is

Table 4
Approaches, definitions and databases for biodiversity protection in certification systems.

International source	Explanation
Convention on Biological Diversity (CBD)	The CBD defines a protected area as "a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives. The CBD is aimed at ecological protection only and has been adopted by 187 countries [123]
Convention on Wetlands	Available list Ramsar areas being wetlands falling under the Convention on Wetlands
Natura 2000 (for Europe)	The Birds Directive requires the establishment of Special Protection Areas for birds. The Habitats Directive requires Special Areas of Conservation to be designated for other species, and for habitats. Together, they make up the Natura 2000 series [176]
World Database of Protected Areas (WDPA)	WDPA contains information on all protected areas that are identified by UNEP-WCMC. The database compiled from multiple resources and is forms a dataset on marine and terrestrial protected areas available [123]
IUCN Database	IUCN has drawn up six categories to represent the international consensus about management types in protected areas, ranging from strict natural reserves to managed resource protected areas [127]
WWF G2000 Ecoregions	WWF identified the Global 200 most biologically distinct terrestrial, freshwater, and marine ecoregions of the planet. Within these ecoregions, WWF pursues ecoregion conservation. A GIS database is available [177]
IUCN Red List of Threatened Species	The IUCN (NGO) Red List provides taxonomic, conservation status, and distribution information on taxa that are facing a high risk of global extinction
Important Bird Areas	The NGO Birdlife International has identified more than 7500 Important Bird Areas in 167 countries and territories [178]
IBAT tool	The Integrated Biodiversity Assessment Tool (IBAT) provides biodiversity information. The tool is the result of a partnership among various NGOs and UNEP World Conservation Monitoring Centre [179]

the Red List assessments, made 10 years or more ago [123]. Updates of these databases rely on actions by individual countries.

Data on the regional identification of important biodiversity areas are also available from geo-referenced data or from satellite images. Examples of the latter [123] are the Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) or ALOS (specific focus on forests and wetlands). The use of satellite images for the identification of biodiversity-rich areas has its limitations, though. PBL [123] mentions that they cannot provide all required detailed information on e.g. the quality of ecosystems: This type of information can only be collected on a national level. Also, updates of GIS data with a sufficiently high resolution may not be available or updated for all regions and countries [124]. Consequently, actual field checks often reveal a different situation than suggested from remote sensing data.

Based on this overview, the following actions are recommended to come to an agreement on how to safeguard biodiversity when producing and using biomass in a region:

- Harmonization in definitions to reach an unambiguous interpretation of terms as 'high biodiversity' or 'biodiverse grasslands';
- Agreement in approach, or a combination of them, how to point out and map biodiversity-rich areas. This includes a decision whether this should include the more subjective HCV approach, currently proposed by various standards;
- Agreement on the minimum required conditions, to be translated into criteria, to safeguard biodiversity-rich areas. Policy measures on local, national and global level should be aligned with the multiple spatial dimensions of biodiversity;
- Further development of approaches to measure and monitor the possible contribution of biomass production to (agro-) biodiversity;
- More work is necessary to complete, harmonize and actualize (including field verification) globally available GIS and remote sensing databases that can be used to map biodiversity-rich areas.

4.3. Soil and water

The overview shows that the need for soil and water conservation is recognized by most standards. The principles and criteria developed for soil and water conservation shows a variation in priorities between standards, partly explained by their different objectives. As example: CERFLOR [125], a Chilean forestry standard, requires "evidence that the road network and fire breakers are maintained in conditions that do not favor soil erosion". RSB [126] demands that "wastes and by-products from processing units are minimized such that soil health is not damaged".

The standards generally use result or process indicators, or a combination of them, to monitor the soil and water conservation:

- *Result indicators:* to monitor the status of soil and water quantity and quality compared to a baseline situation. A soil and water analysis is required.
- *Process indicators:* developed to maintain or enhance the soil and water quantity and quality. Demonstration of good and/or the demonstration of a management plan or strategy are required.
- In addition, most standards require a risk assessment for new plantings.

Some standards specify the parameters that should be included in the soil and water analysis (see Tables 5 and 6). If defined, the amount and type of required parameters differ per standard. As example, the UK-RTFO [127] requests an analysis, unlike most other standards, on 'soil salts content'. RTRS [96] requires on the other hand the measurement of the quality of residues. Some consensus (see Tables 5 and 6) on suitable parameters on production unit level can be found as well, though. Often used parameters are:

- Soil quality: N, P, K, SOM and pH;
- Soil quantity: soil loss and estimation of residues;
- Water quality: BOD;
- Water quantity: water use in l/ha/year.

There is a difference in the explicitness of the indicators applied in a standard. BSI requires for example that <50 kg water/kg cane is used in the agricultural production [98]. The relatively limited geographical area for sugar cane production makes it possible to give one quantitative threshold for all BSI users [98]. For other standards, the quantitative indicators are less defined. Key reason is in most cases that the threshold for an indicator (e.g. water use) is too differentiated for the multiple crops, regions and agricultural systems that are included in the standard. Various standards, as FSC or RTRS, develop therefore country specific indicators that are proposed by national working groups. Fig. 6 gives an interpretation, based on this overview, of the key factors that define the explicitness of C&I in a standard. Note that vagueness of indicators may result in open interpretations by the certifying companies. This has as main disadvantages that there is lack of transparency and free space of interpretation whether a production unit complies with a criterion or not.

Table 5
Identified criteria and indicators for soil quality and quantity for selected standards[a] [21,24,63,76,87,96,98,117,118,125,126,173,180,181]. Excluded in this table is the overview of required measures that demonstrate compliance in management activities. Also excluded: required first measures on new sites as EIA/risk assessment (both are shortly discussed in text). • = Included.

	RSB	RSPO	RTRS	BSI	NTA808	UK-RTFO	Greenergy	ISCC	Global-GAP	SAN	CERFLOR[f]	FSC
Records of fertilizer/agrochemical inputs[b]	•			•			•		•		•	
Records and monitoring (incl. analysis, translation to management plans)	•	•	•	•	•	•	•		•	•	•	
Identification of soil types on each site of area									•	•		
Maps of (fragile) soils are available	•						•			•		
Compliance of relevant laws and regulations[b]					•	•	•					
Indicated parameters for analysis soil quality												
Soil organic carbon												
Soil organic matter	•[c]		•	•	•	•						
pH soil		•	•	•[d]	•	•						
Nitrogen			•		•	•	•		•			
Phosphorous			•		•	•	•		•			
K					•	•	•					
Quality surface residues			•									
Soil suitability for intended crops									•			
Soil salts content						•						
Indicated parameters for analysis soil quantity												
Soil loss in tons/ha per year					•	•						
Quantity and use of surface residues			•	•	•				•			
Info on susceptibility soil to erosion				•[e]					•			
Info on conformation, slope, land form									•			
Info on wind exposure soil									•			
Field observations on evidence (or not) from erosion or evidence of practices							•		•			
Plans and strategies mentioned												
Soil management plan or strategy			•	•[e]		•	•			•		
Nutrient recycling strategy specifically mentioned	•											
Specific strategy or plan to minimize risk erosion	•		•			•	•	•		•		•[g]

[a] EC-RED and US-RFS are not included here as they do not discuss this principle.
[b] Indicated when specifically mentioned under principle for soil quality and quantity.
[c] RSB: The optimal level of organic matter is to be defined through local consultation.
[d] Verifier BSI: >80% of analyzed samples within acceptable pH limits.
[e] As part of required reporting in Environmental Management Plan.
[f] Only for planted forest.
[g] Guidelines have to be prepared.

The performance indicators in Tables 5 and 6 focus mainly on the local ('micro') level and their system boundary is the production unit. Note that small performance changes on a micro-level may, however, result into cumulative impacts on a meso- or macro level. Examples are the impacts of water use on various production units on a watershed or the risk for pollution along the river stream because of pesticide use from individual producers. Activities outside the production unit may, vice versa, also affect water resources within the system boundary. This interaction between factors and impacts on micro- and meso-level is currently hardly addressed in the initiatives as the meso-level forms no part of the standard's system boundary.

The overview shows that various actions are needed to develop a unified set of principles and C&I for soil and water conservation in a biomass production area:

- Agreement on a unified set of principles and C&I (possibly combined with additional ones) to guarantee soil and water conservation on a production unit level.
- Further discussion and clarification on the applied system boundaries in a standard to clarify which part of the impact is the producer's responsibility and which part is outside his scope.
- Linking a unified set of local C&I to regional, national and international databases and models to be able to monitor and report changes in water quantity and quality on a meso- and macro-level. Note that various standards have based their principles on inter-governmental processes. For example: FSC [76] principles are based on ITTO principles. This type of interaction facilitates using locally measured indicators for monitoring progress on a macro-level.

4.4. Other environmental principles

Most initiatives have included environmental principles in addition to the ones mentioned in the previous sections. These can be included in a standard to meet specific environmental concerns from stakeholder groups, products or geographical regions. Table 7 shows some of these environmental principles to highlight the variety in topics that are covered in the various initiatives included in this overview.

4.5. Socio-economic principles

Socio-economic principles refer to principles that guarantee local prosperity and the social well-being of employees and the local population. With the latter, a distinction can be made between negative effects on human rights and other issues related to social well-being as working conditions, respecting official property rights, and food security.

Several of these issues are embedded in (non-legal and not binding) international declarations and conventions. Examples are the 'Universal declaration of Human Rights'[8] [128] or the

[8] Article 23 in the 'Universal declaration of Human Rights' (1948) discusses the right to work, free choice of employment, favorable working conditions, the right to equal pay for equal work (non-discrimination) and the right to form and to join trade unions for the protection of his interests.

Table 6
Identified criteria and indicators for water quality and quantity for selected standards[a] [21,24,63,76,87,96,98,117,118,125,126,180,181]. Excluded in this table is the overview of required measures that demonstrate compliance in management activities. Also excluded: required first measures on new sites as EIA/risk assessment (both are shortly discussed in text). • = included.

	RSB	RSPO	RTRS	BSI	NTA808	UK-RTFO	Greenergy	ISCC	Global-GAP	SAN	CERFLOR[4)]	FSC
Monitoring of water used for irrigation[b]			•	•					•	•		
Records and monitoring (incl. analysis, translation to management plans)	•	•	•	•	•	•	•	•	•	•	•	
Compliance of relevant laws and regulations[b]					•	•						
Address effects of water use on local resources		•						•				
Indicated parameters for analysis water quality												
Temperature			•									
Dissolved oxygen			•									
Nitrogen			•					•		•		
Phosphorus			•							•		
Turbidity			•									
BOD level on/near production unit		•		•	•	•				•		
Total suspended solids in mg/l				•						•		
Agrochemical inputs in input/ha/year						•	•					
Origin of (irrigation) water				•[c]	•					•		
Indicated parameters for analysis water quantity												
Net water consumed per unit mass of product				•								
Mill water use per ton of FFB		•										
Use of (irrigation) water sources in l/ha/yr					•	•						
Data records for irrigation prediction									•			
Plans and strategies mentioned												
Water management plan	•	•		•[c]		•	•			•		
Plan or documentation indicating best practices			•			•	•					
Plan for minimizing subsidence of peat soils	•											

[a] EC-RED and US-RFS are not included here as they do not discuss this principle.
[b] Indicated when specifically mentioned under principle for water quality and quantity.
[c] As part of reporting in Environmental Management Plan.

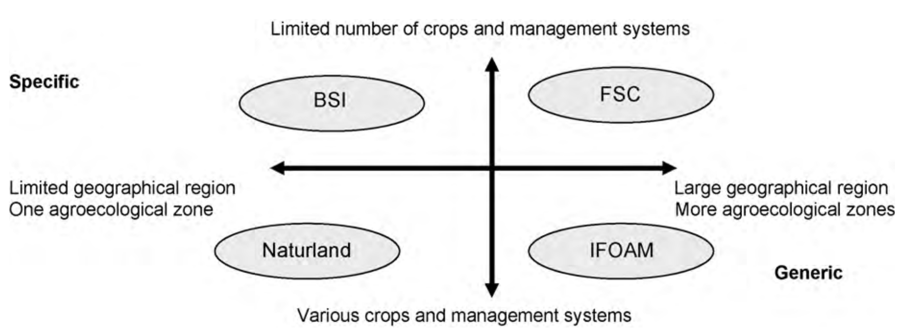

Fig. 6. Parameters defining the specificness of criteria and indicators in a standard.

'Declaration on the Rights of Indigenous Peoples'[9] [129]. The International Labour Organization (ILO) has developed a system of international labour standards to safeguard social security worldwide. ILO standards are translated in the form of Conventions and Recommendations[10] [130]. Performance is monitored by a regular supervision process by ILO and based on state reports [131]. Relevant ILO standards to safeguard social security in the bioenergy value chain [130,132] are indicated in Table 8.

Most voluntary standards in the field of bioenergy, forestry and agriculture have included principles to safeguard the socio-economic well-being of their employees. Table 8 shows an overview of some of the principles included by standards. Additional principles (not shown in Table 8) that are generally included as well are safe and healthy working conditions, payment of salary and providing regular employment. There is a mutual agreement that the ILO standards serve as a profound and consistent basis to develop socio-economic principles for workers. Compliance of these principles is generally verified by proof of procedures or mechanisms, supported by documentation and records.

The socio-economic principles proposed by (intra)-government initiatives as the UK-RTFO and the Netherlands (NTA 8080) are not obligatory in implementation. UK-RTFO requires a report from the producer on its socio-economic performance. Meeting the socio-economic principles, as laid down in NTA8080, is a condition for obtaining subsidy for bioenergy for heat and power in the Netherlands. Implementation is in all cases voluntary based and non-obligatory.

One of the main reasons for choosing this pathway is WTO legality. Important aspects to consider avoiding WTO disputes are the exceptions mentioned by article XX GATT (see also [80]), the presence of a territorial link and the justification of international treaties. Principles as socio-economic well-being and local

[9] The Declaration on the Rights of Indigenous Peoples (2007) sets out the individual and collective rights of indigenous peoples.
[10] Conventions are international treaties that, once adopted by the Conference, are open to ratification by member States. Ratification creates a legal obligation to apply the provisions of the Convention in question. Recommendations, on the other hand, are intended to guide national action, but are not open to ratification, and are not legally binding.

Table 7
Indication of variety of environmental topics included in standards apart from 5.1 to 5.3. • Included as principle, ○ mentioned explicitly in criteria or included as separate criterion, and – not mentioned.

Topics:	EC-RED	US-RFS	NTA 8080	UK-RTFO	RSB	RSPO	RTRS	BSI	ISCC	SAN	Global-GAP	IFOAM	FSC
Good (farming) practices	•	–	○	○	•	•	•	•	–	•	○	•	○
Waste	–[b]	–	○	○	○	○	○	○	–	•	•	○	○
Air	–[b]	–	•	•	•	○	–	○	–	–	○	○	–
Fire	–[b]	–	○	–	○	○	–	–	–	○	○	○	○
GMO	–[b]	–	–	–	○	○	–	○[c]	–	–	○	•	○
Pesticide management	–[b]	–	○	○	○	○	○	○	•	○	•	•	○
No invasive species	–[b]	–	–	–	○	○	–	–	–	–	–	•	○
Hygiene, quality product[a]	–[b]	–	–	–	–	–	–	○[d]	–	–	•	○	–

[a] Not referring to safety and hygienic conditions for employers.
[b] *Note*: regulation on good farming practices refers to EU regulations which include various environmental topics.
[c] To be discussed in mitigation plan.
[d] Criterion: "To continuously improve the quality of sugarcane and products from the sugar mill".

prosperity are typically bounded to a country's boundary and do not show a territorial link with a biomass importing country. Differences in social circumstances are therefore not seen as a justification for trade limitations [80]. In exceptional cases it could be argued that measures are justified for the prevention of human rights violations (broadly recognized) and aimed at 'the protection of public morality' (art. XX GATT) [80]. A similar argumentation is also valid for various environmental principles.

Principles to safeguard the social well-being of local people around the production unit are less uniform and defined (see Table 9). The overview indicates a general agreement that the following principles are (at least) required:

- Mechanisms to secure property rights or tenure.
- Procedures for communication and consultation with local communities.
- Implementation of a Social Impact Assessment.

Some of the standards have also included additional principles. Standards differ, however, in their opinion which measures should be incorporated in a standard to guarantee or develop the well-being of surrounding communities. Table 9 shows that measures range from education support (SAN, FSC) to support of local economic activities (NTA8080, SAN, FSC), fair prices (RSPO), prohibiting the replacement of staple crops (ISCC) or to avoid food insecurity (RSB).

RSB [126] assesses food security according to four component concepts: food availability, access, utilization and stability (versus vulnerability). The socio-economic and market impacts of bioenergy on local food security are highly complex: Food availability can for example be affected by disruptions to the food transport and production systems or changes in import and export tariffs. Food access can be negatively influenced by unemployment [126]. This implies that social well-being or food security in a region cannot be simply analyzed by one single parameter.

Table 8
Overview of selected principles on social well-being of workers included in various standards [16,21,39,46,48,61,63,69,76,87,89,96,98,117,118,126,127,132,160,174,175,180–187]. It is indicated in the table if a reference is made to ILO or UN declarations. • = Included and – = not included.

	No child labour	Minimum age (years)	Freedom from discrimination	Freedom of labour; no forced labour	Freedom of association and collective bargaining; freedom to organize and negotiate	Right of indigenous people explicitly mentioned
EC-RED	–	–	–	–	–	–
US-RFS	–	–	–	–	–	–
NTA 8080	• (UN)[f]	–	• (UN)[f]	• (UN)[f]	• (UN)[f]	• (UN)[f]
UK-RTFO	•	15[b]	• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	–
RSPO	• (ILO 138,182)	15 or older[b,c]	• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	• (ILO 169)
RTRS	• (ILO 138,182)	15 or older[b,c]	• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	–[d]
BSI	• (ILO 138,182)	15 (non-hazardous) 18 (hazardous work)	• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	• (ILO 169)
RSB	• (ILO 138)	14 or older[b,c]	• (ILO 111)	• (ILO 29)	• (ILO 87,98)	• (ILO 169)
ISCC	• (ILO 138,182)		• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	–
SA 8000	• (ILO 138)	15 (14 under ILO)[a]	•	•	•	–
ETI code	• (ref. to ILO)	–	•	•	•	–
FLO	•	15	•	• (ILO 29,105)	• (ILO 110)	–
GlobalGAP	–	–	–	–	–	–
SAN	• (ILO 138)	15 or follow ILO	• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	–
FSC	• (refers to ILO)	–	• (refers to ILO)	• (refers to ILO)	• (ILO 87,98)	•
PEFC	• (ILO 138,182)		• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	–[e]
IFOAM	•[a]	–	•	•	•	–
GGL	–	–	–	–	–	–
Greenergy	•	16[b]	• (ILO 100,111)	• (ILO 29,105)	• (ILO 87,98)	•
SWAN	•/– (UN)[g]	–	–	•/– (ILO 29,105)[g]	•/– (ILO 87,98)[g]	•/– (UN)[g]
Laborelec	–	–	•	–	–	–

[a] Minimum lowered to 14 for countries operating under the ILO Convention 138 developing-country exception; remediation of any child found to be working.
[b] With the exception of family farms as further described in criteria.
[c] Older if defined in national regulation
[d] Traditional communities affected by expansion of soy bean areas are compensated.
[e] PEFC published a position Paper on "Tribal and Indigenous people, local people, local communities, forest dependent communities and the PEFC Council" in 2005 [77].
[f] Practices in accordance with the UN 'Universal Declaration of Human Rights".
[g] "The licenceholder must ensure that biomass and other raw material producers and the fuel producer have plans in place for fulfilling UN and ILO Conventions".

Table 9
Overview of selected principles on well-being of local communities included in various standards [21,24,61,63,76,87,96,98,117,118,126,188,189]. • = Included, – = not included.

	EC-RED	US-RFS	RSB	RSPO	RTRS	BSI	NTA808	UK-RTFO	ISCC	Greenergy	SAN	FSC	CCBS[h]
Legal and customary rights (property rights)	–	–	•	•	•	•	•	•	•	•	•	•	•
Procedures			•	•	•		•	•				•	
Proof of ownership			•	•	•	•[a]	•	•	•	•	•	•	•
Compensation systems available			•	•	•		•					•	
Well-being local communities	–	–	•	•	•		•	–	•	–	•	•	–
Contribution towards local economy and activities							•[b]				•	•[g]	
Fair and transparent prices available				•									
Compensation for use traditional knowledge												•	
Preference employment of local people					•						•	•[f]	
Local procurement services and inputs					•								
Support local education											•	•[f]	
Safeguarding local food security			•[c]						•				
No replacement of staple crops			•						•				
Use of (co-) products does not affect traditional/local use			•			•	•						
Participation/communication local people	–	–	•	•	•	•	•	•	•	•	•	•	–
Procedures or methods established				•	•	•	•	•	•	•	•	•	
Complaints and grieving mechanism				•	•	•			•		•	•	
Social Impact Assessment in participatory way	–	–	•	•[d]	•	•	•[e]	–	–	•	•	•	•
Existence of social management plan											•	•	•
Specific measures to target vulnerable groups			•										
Take measures to counteract negative effects						•	•			•			•
Mentioned parameters for SIA are:	–	–	•	•	–	–	•	–	–	•	–	•	•
Access and use rights/land tenure			•	•			•			•			•
Physical and economic displacement							•						
Economic livelihoods, working conditions			•	•						•			•
Job creation and potential loss			•										
Subsistence activities			•	•									•
Cultural and religious values			•	•			•					•	•
Gender differences							•						
Health and education facilities			•	•			•						
Other community values				•									•

[a] BSI: Guidance on customary rights is provided in ILO Conventions 169 and 117.
[b] Reporting indicators based on Global Reporting Initiative on the basis of Economic Performance Indicators EC 1, 6 and 7.
[c] Only valid for food insecure regions.
[d] The ILO Decent Work Agenda is a recommended tool for assessing local impacts.
[e] On the basis of the Social Performance Indicator SO1 of the Global Reporting Initiative.
[f] Communities within, or adjacent to, the forest management area should be given opportunities for employment, training, and other services.
[g] Forest management and marketing operations should encourage the optimal use and local processing of the forest's diversity of products.
[h] Specifically for project design and development.

The Bioenergy and Food Security (BEFS) project from FAO works on the development of a set of C&I to define the impacts of bioenergy production on food security [133]. The RSB guidelines on food security provide an inventory of food security indicators that should be used in different contexts and at different scales [134].

In addition, various initiatives refer to useful, existing approaches that could be used to measure or monitor the social well-being of local communities:

- NTA8080 [21]: The social and economic performance indicators of the Global Reporting Initiative to monitor the social well-being of local communities;
- IFOAM refers to the *Argencert* social score system, following the Harmonized Social Standard [135];
- CCBS: tools and methodologies for stakeholder assessments as community impact monitoring, resource assessments and community benefits [84];
- RSB/FAO: the Food Security Impact Assessment (FSIA) assesses impacts on local food security, indicating the likelihood of significant impacts to local food security from a biofuels operation [134].

Concluding, the ILO labour standards form a sound basis for a harmonized use of socio-economic principles on the well-being of employees. Measuring the social well-being of a community is more complicated because (i) impacts cross the standard's system boundary and (ii) the complexity of interrelating factors influencing social well-being. The following actions are recommended to develop a unified set of principles and C&I to measure social well-being:

- Agreement between initiatives to use the ILO labour standards as key reference to measure and monitor the social well-being of employees in a production unit;
- Explore the possibilities to include socio-economic principles in a certification system for bioenergy (also developed on a government level) in spite of WTO restrictions. Possibilities include linking compliance to subsidies or the development of a voluntary "golden plus" standard that includes and rewards compliance of socio-economic principles;
- Given the importance that is given by many (developing) countries (see Section 2) to the social well-being of local communities, the development of a suitable approach to measure and monitor this principle is highly needed. The work from RSB and FAO, and other available tools, could offer a useful basis for further development.

4.6. Indirect Land Use Change (ILUC)

There is widespread agreement that competition for land for agriculture, infrastructure or other uses exists [136]. Land use changes are thus not unique to bioenergy but covers all activities that affect land use [137]. The cultivation of energy crops requires

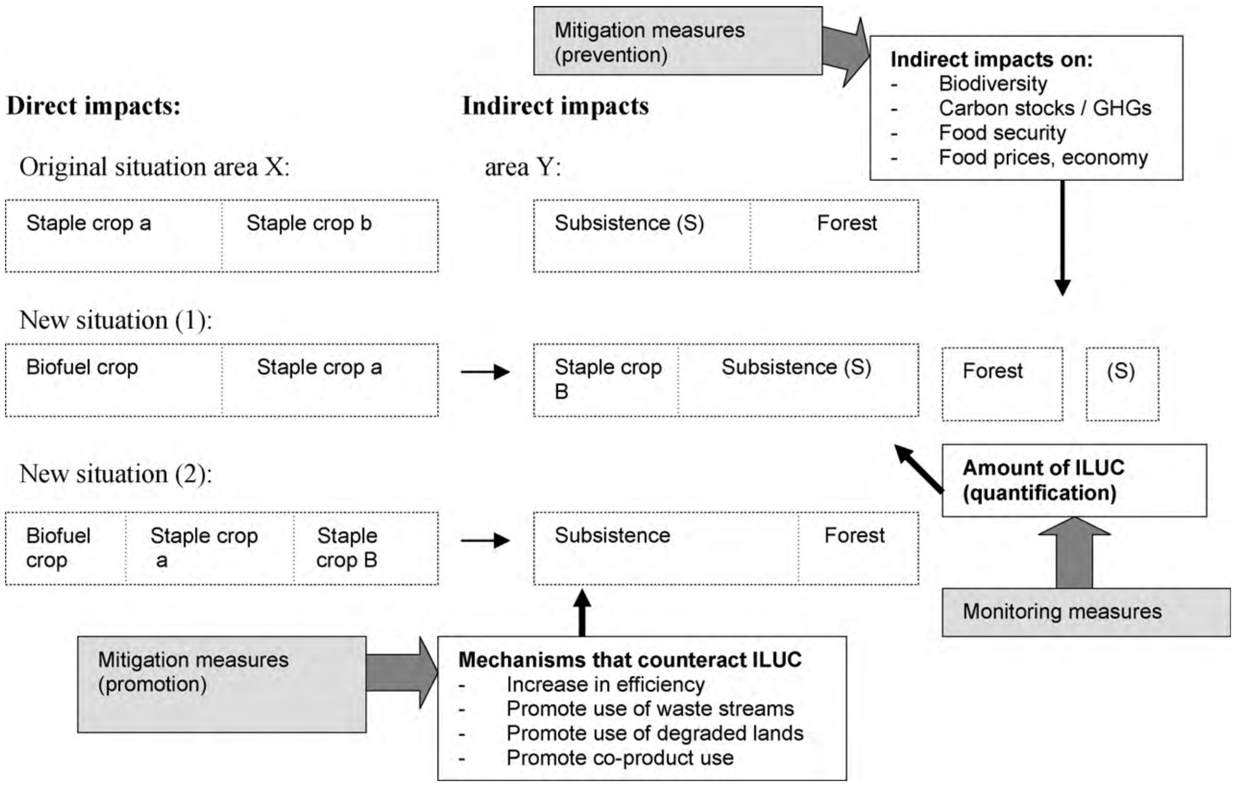

Fig. 7. Proposed measures to monitor or counteract ILUC. Mitigation measures (prevention)

land, just like crops for food, feed and fibre. To 2050, global demand for food, feed and fibre is expected to grow by 70% while, increasingly, crops may also be used for bioenergy and other industrial purposes [138].

Direct LUC effects (dLUC) – e.g. change in land cover – are the effects that can be directly and exclusively linked to the production unit of the bioenergy chain. *Indirect* LUC (ILUC) effects are the effects that are caused by the introduction of a bioenergy product, but cannot be directly linked to the production unit. These indirect effects can be ecological, environmental, social or economic. Examples are indirect losses of biodiversity-rich areas or increased N_2O emissions due to agricultural intensification [139]. Several of these impacts are also interrelated. For example, deforestation of tropical rain forest will have a negative impact on carbon stocks (GHG emissions) or soil conservation, see also [114].

The mechanisms that determine the contribution from intensification, land conversion or changes in consumption, depend on many parameters, which can vary between countries and regions [139].

The possible negative effects from ILUC from bioenergy production appeared on the political agenda after the publication of some scientific studies [5,6,12]. These studies have their focus on first generation biofuels and discuss mainly the possible impacts of ILUC on carbon stock changes and, to a lesser extent, on biodiversity (see Fig. 6). Recently published reports [139,140] also discuss the possible impacts of ILUC on socio-economic circumstances or water use. The question whether and how to include ILUC in a certification system or in a regulatory context is still widely discussed [136]. Generally speaking, proposed measures to regulate ILUC are twofold (see Fig. 7), which will be discussed one by one:

- Monitoring measures;
- Mitigation measures; Mitigation measures focus on prevention or promotion measures, or on a combination of them.

4.6.1. *Monitoring measures ILUC*

There is currently an ongoing debate whether and in how far bioenergy production will contribute to the increase or decrease of agricultural land use and, consequently, to additional indirect socio-economic or environmental impacts. No general consensus exists (yet) on whether impacts of ILUC are actually significantly large and if so, how large exactly. Of course, this is also highly location and case specific. Lack of consensus has led to the development of initiatives that aim to quantify the impact of future additional bioenergy demand including some or all indirect impacts. To quantify the ILUC-factor, a distinction can be made between methodologies (under development) that use a simplified, aggregated approach and more complex methodologies that are based on equilibrium models.

4.6.1.1. Simplified approach to quantify ILUC. The *Risk Adder approach*, developed by the Oeko-Institut, gives an estimation of the risk for ILUC and, consequently, additional GHG emissions. No differentiation is made between dLUC and ILUC emissions. The key question is to determine *where* ILUC takes place. The approach assumes that, from a global point of view, only those countries are affected that act as exporters in world trade–they are the only ones that enjoy incentives for additional production and can therefore trigger indirect LUC. Opponents argue, however, that this approach "punishes the best and rewards the worst" [7,115]. The potential CO_2 emissions from ILUC are simplified and determined as the mean value of proportionate areas required for agricultural exports by world regions and the relevant C release by the LUC there [124].

Ecometrica developed [141] a practical three-step approach to quantify the GHG emissions from ILUC associated with different biofuel feedstock within the context of changing patterns of global land use. The approach estimates ILUC emissions associated with marginal changes in output of commercial agricultural crops based on a share of actual ILUC emissions. This approach uses the same ILUC emission factor for all biofuel production systems. This means

Table 10
General four-step approach initiatives to model ILUC in global models, based on [7].

Step	Description
Additional biofuel demand (mandate, market) >>>	
1. Market response calculated	*Global agro-economic equilibrium models*: Statistical models that couple demand to required production Effects are divided into: Intensification of production (yield levels) Commodity prices > trends in food consumption Expansion of agricultural land
2. Land use change	*Agro-ecological models*: GIS models that couple required production to land use change. Prediction is made on which types of land will be converted to agricultural land. One method used for this purpose is satellite analysis of historical LUC trends
3. Impacts: biodiversity and carbon stocks	*Assessment of impacts*: Datasets are needed as soil organic carbon data, IPCC data sources or protected areas (models that couple land use change to sustainability impacts)
4. Time allocation	*Allocation* of GHG emissions over time (time horizon is chosen)

that different yields and performances of energy crops are neglected [101].

4.6.1.2. Modeling approaches to quantify ILUC. Recently, the quantification of indirect impacts has generally been performed by using global agro-economic equilibrium models. As visualized by Cornelissen and Dehue [7], a four-step approach is generally used by the available initiatives for quantifying indirect impacts of bioenergy production (see Table 10).

There are many research groups studying ILUC. Consequently, there are some first initiatives that aim to assess the impacts of ILUC because of bioenergy production. Most initiatives make use of Computable General Equilibrium models (CGE) or Partial Equilibrium models (PE). *Computable General Equilibrium* (CGE) models are global models that cover the whole world economy, disaggregated into regions and countries as well as diverse sectors of economic activity. *Partial Equilibrium* (PE) Models focus in most cases on the agricultural sectors. They generally allow for a detailed representation of agricultural and bioenergy production and land use restrictions [142]. The most relevant equilibrium models that have studied (indirect) LUC from bioenergy production are shown in Table 11.

The US-RFS is using the *FAPRI and FASOM* models to quantify changes in impacts on the agricultural sector, both domestically and on an international level [143]. FASOM simulates the allocation of land over time due to policy alternatives (from bioenergy development) to competing activities in both the forest and agricultural sectors and the associated impacts on commodity markets. The FAPRI model is used in particular to analyze different US biofuel support but also some international bioenergy scenarios with exogenous increases in different world regions [142].

The *GTAP-CGE model* (used by LCFS in combination with the GREET model) and database have been extended to improve the treatment of biofuel by-products and accurately represent global land use. The modified database includes data on production, consumption and trade of biofuels including grain-based ethanol, sugarcane ethanol, and biodiesel from oilseeds, as well as data on biofuel by-products [144].

The LEI-IMAGE model is under development by PBL in the Netherlands. LEI modified GTAP by including energy substitution in the standard model. The GTAP-E model includes crop yields, land cover, climate feedbacks and GHG emissions, handled by the spatial biophysical model IMAGE [140].

A recent study from *IIASA* provides an integrated agro-ecological and socio-economic assessment of the social, environmental and economic impacts of biofuels. The scenario-based quantified findings of the study rely on a modeling framework, based on the FAO/IIASA Agro-ecological Zone model and the IIASA global food system model [145].

The European *Joint Research Centre (JRC)* is developing an ILUC-factor, based on a similar modeling approach as applied in the USA [146]. In 2009, JRC implemented an assessment on existing models and datasets that could be used. A comparison between the models gives insight in the uncertainty level of the outcomes.

Various studies [6,7] have discussed the different outcomes and insecurities of the models discussed above. Cornelissen and Dehue [7] indicate that the extent of cropland expansion ranges from 4 ha/MJ (IIASA, LCFS) to 7 ha/MJ (US-RFS) or 9 ha/MJ (Searchinger). This variation in modeling results is caused by uncertainties and differences in assumptions included in the models. Some of them are [137,142]:

- Future production and trade patterns of bioenergy; historical patterns and datasets are not available for this sector and models use various approaches to calibrate these patterns over time;
- Land use change; Models use various assumptions on productivity changes and differ in the number of agroecolocial zones and land uses included in the model;
- By-products from bioenergy, which can be used to meet regional food and feed demands, are not widely included in models yet;

Table 11
Key CGE and PE models that have aimed to include LUC from bioenergy and their characteristics, based on [142].

Model types[a]	Model type		Key users of model	Bioenergy sector included	
	CGE model	PE model		Biofuels	Electricity
FAPRI model		•	US-RFS, FAPRI	•	
FASOM model		•	US-RFS	•	•
AGLINK/COSIMO		•	OECD/FAO	•	
GTAP-E	•		LEI	•	
GTAP- versions	•		LCFS		
IMPACT		•	IFRPI	•	

[a]More CGE and PE models can be mentioned; the most relevant ones are included in this table.

Table 12
Overview of included monitoring and mitigation measures to prevent ILUC in selected initiatives (• Included, ○ in consideration) [7,16,21,24,30,46,63,98,118,126,143,190,191].

	US-RFS	LCFS	Massachusets	EC-RED	UK-RTFO	NTA8080[e]	RSB	BSI	RTRS	RSPO	Greenergy	RCA
Monitoring measures												
Reporting (food) prices				•	•	•						
Reporting LUC				•	•	•						
Reporting food availability				•	•	•						
GHG reduction requirement	•	•	•	•	•	•	•	•	○	○	•	
Mitigation measures												
ILUC-factor	•	•		○			○				•	
No reduction in carbon stocks	•/–[b]	•/–[b]	•/–[b]	•	•	•	•/–[b]	•/–[b]	○	○	•	•
No production on HCV areas				•	•	•	•	•	•	•	•	•
No competition food production							•					
No displacement effects												•
Land use rights[a]							•		•[c]	•		•
Minimize negative social and environmental impacts of expansion							•	•	•	•	•	
Promotion measures												
Promote use of residues/waste			•		○	•[d]	•					
Promote use of degraded land				•			•	•[f]				
Efficiency increase					○		•	•				

[a] Only indicated when explicitly mentioned for new plantings. See also section 5.5.
[b] Indirectly by including land use change in GHG calculation (with defined GHG reduction requirement).
[c] Compensation for new lands is acknowledged.
[d] Ministerial regulation "Double counting sustainable Biofuels" from 9 December 2009 which promostes biofuels produced from waste, residues and lignocellulosic materials [192].
[e] Excludes recommendations from CBD Commission in the Netherlands.
[f] Following guidelines EC-RED to promote use of degraded lands in GHG calculation.

- Technology changes over time; Models differ in their capability and assumptions to include technology changes over time. Few models have included second generation crops in their model database;
- Impacts from ILUC; Not all model applications include emissions from N_2O and CH_4 emissions from agriculture. Result variations are also influenced by allocation methods (where does LUC take place).

In all cases, an ILUC-factor remains an approximation of reality and aggregation to some extent (region-, time- and crop-specific) is inevitable. A key question in the current debate is if and when models and required input data are scientifically good enough to translate outcomes to a regulatory context. This is still unknown. For further improvement, the following actions are recommended:

- Improvement of global agro-economic equilibrium models to model ILUC as accurately as possible.
- Harmonization of parameters, databases and assumptions used in agro-economic equilibrium models to come to comparable outcomes between initiatives.
- For improvement of the models, understanding of the drivers, and mitigation of future impacts, monitoring and data collection (see also Table 10) of land use changes and its impacts on a regional level is crucial.

4.6.2. Mitigation measures ILUC: prevention or promotion measures or a combination

Various initiatives have included *prevention measures* to avoid the negative impacts of ILUC. One of the proposed solutions is to include additional GHG emissions in a LCA with the use of the ILUC-factor (see also Section 4.6.1). In case the calculated GHG balance exceeds the obliged GHG reduction performance, the crop-based production unit is excluded for bioenergy use.

Both US-RFS and the LCFS (State California) have included an ILUC-factor in their policies. The *Energy Independence and Security Act* (EISA) states that ILUC must be included in GHG emission reduction calculations [136]. The Environmental Protection Agency is currently developing ILUC-values for several feedstock in the US-RFS [147]. The *LCFS* has included an ILUC-factor as well in its regulation. Some outcomes for crop-based biofuels (e.g. biofuels from sugarcane in Brazil) indicate that land use changes are a significant source of additional GHG emissions resulting in exceeding the demand of 20% GHG emission reduction [31].

The outcomes of the calculated ILUC-factors, as proposed in the US, are under debate and countries as Brazil, directly influenced by these considerations, make stringent efforts to accurately assess the real LUC effects that have occurred as result of expansion of biofuel crops in their country [6]. Note that the US-RFS and the LCFS contain an incentive for producers to choose a feedstock with little or no emissions from ILUC. For a given feedstock, the RFS does not provide any incentives for producers to change their behavior such as to minimize the risk of ILUC. The LCFS has indicated that this is subject for further investigation and consultation in the future [7].

EC-RED and various other initiatives (see Table 12 and Section 4.2) have included measures in their standard that place restrictions on new plantings with the aim to prevent LUC on carbon and biodiversity-rich areas. Note that these measures are directed to prevent *direct* LUC and will therefore not be sufficient to prevent ILUC (see Fig. 7). Initiatives as RSB, ISCC combine these restrictions with additional prevention measures as avoiding food insecurity or no competition with food production. Although these are steps in the right direction, they will not be sufficient in areas where ILUC is driven by other factors or by other feedstock (Fig. 8).

EC-RED does not (yet) contain explicit measures aimed at reducing unwanted indirect impacts. End of 2010, the EC shall report on the indirect impacts of biofuels including proposals on how to minimize unwanted indirect impacts. The EC recently consulted on a number of options for dealing with indirect impacts from biofuels. Some of them go beyond the prevention measures outlined in Table 12 [7]. Examples of these options are extending the restrictions on LUC that will be imposed on biofuels consumed in the EU to other commodities/countries, international agreements on protecting carbon-rich habitats or extending the use of bonuses for production models with limited chance on ILUC.

It is also possible to *develop promotion measures* that limit ILUC and, consequently, possible negative impacts. ILUC can be partly or

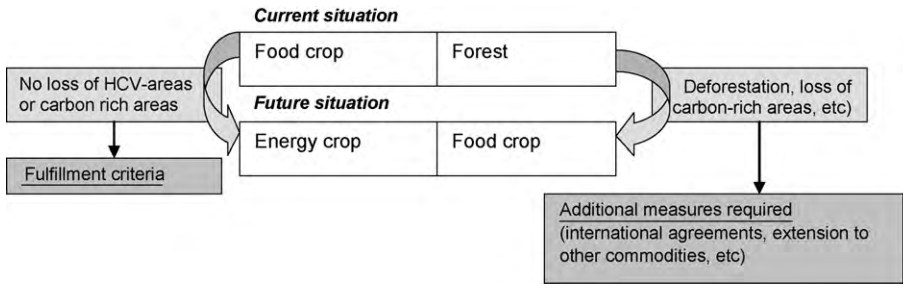

Fig. 8. Illustration of (insufficient) mitigation measures to avoid ILUC in current initiatives.

fully compensated by higher efficiencies in agriculture and livestock [148,149]. This line of thinking is the basis for various biomass potential studies [148,150]. Initiatives as RSB and BSI (see Table 12) have included measures to promote the intensification and efficiency of agricultural production in their standard.

Another approach to limit the impacts from ILUC from bioenergy production is to promote the use of marginal or degraded lands or waste residues The *State Massachusetts* announced in 2009 that only waste-based biofuels are guaranteed to meet the state's renewable fuel standards at this stage [30] until final ILUC emissions for fuel pathways are determined [151]. The current EC-RED [16] proposes a 'bonus' on the GHG balance (29 g $CO_{2\text{-eq}}$/GJ) for biofuels that are produced on degraded, marginal or polluted lands. The possibilities and limitations of the use of marginal or degraded land are, however, still uncertain. Examples of aspects that need to be taken into consideration are: defining degraded lands and translating this into policy measures, the possible significant value of degraded lands in terms of carbon stocks or biodiversity or the existing function of marginal or degraded lands for local communities.

Beside, there are a limited number of initiatives that develop approaches to mitigate impacts from ILUC, based on an *integrated approach of prevention and promotion measures*. Examples are the proposals from RCA, the CBD (Netherlands) and the Renewable Fuels Agency (RFA) in the UK.

The *Responsible Cultivation Area* (*RCA*) initiative is a private sector initiative coordinated by Ecofys in collaboration with NGOs and industrial parties. The initiative provides a set of criteria that together define requirements for RCAs. A methodology is developed to identify RCAs, focusing on expanding production on land without provisioning services and on increasing land productivity [7].

The *RFA* (*UK*) [152] commissioned work, as follow-up of the Gallagher Review [8], to develop a methodology that can objectively distinguish energy crops with a low risk of indirect effects. The proposed criterion for bioenergy feedstock production with a low risk of indirect effects is: "Additional production has been realized without displacing existing provisioning services of the land". Compliance is possible through three options: (i) the use of land without provisioning services, (ii) increasing land productivity through integration with non-bioenergy feedstock systems and (iii) increasing the land productivity of existing bioenergy feedstock systems. The RFA intends to include this methodology under the RTFO from April 2010 to enable individual companies to initiate biofuels projects with a low risk of indirect effects.

The *CDB* (*the Netherlands*) recommends a set of three coherent measures that recognize the significance of ILUC on GHG emissions and biodiversity and, at the same time, offer incentives to make agriculture sustainable and more efficient [153]:

1. Calculate an ILUC value for each group of crops on the assumption that the use of 1 ha of agricultural land for biofuel production entails the use of one additional hectare of agricultural land;
2. Vary the application of the ILUC value proportionally in accordance with the following conditions: (i) demonstrated significant improvements in efficiency of agricultural production; (ii) use of degraded or marginal land and (iii) set off for co-products that enter the food or animal feed supply chain;
3. Protect biodiversity including availability of funding sources for biodiversity and forestry programs and promoting strategies on biodiversity conservation and poverty reduction.

CDB will discuss the relationship between biofuels and food supply in greater depth in future work [153].

Concluding, it is widely acknowledged that additional measures are needed to minimize ILUC impacts from bioenergy production. Similar concerns are also valid for food and feed production. Nevertheless, current initiatives have rarely captured impacts from ILUC in their standards. Available approaches include measures to avoid (direct) negative LUC impacts – mainly on GHG emissions and biodiversity – combined with promoting business models that demonstrate low risks of indirect effects. The following actions are recommended to further develop measures to mitigate impacts from ILUC:

- Extending measures, mainly focused on mitigating impacts of ILUC on GHG emissions and biodiversity, to other socio-economic and environmental aspects as food security or social well-being;
- Extending measures to mitigate impacts from ILUC to all lands and commodities;
- Specifying measures to micro, meso and macro level to improve effectiveness;
- Combining mitigation measures with strong international agreements (see Fig. 9);

5. Implementation issues of a sustainability standard

Procedures and solid (documentation) systems are needed to implement a reliable certification system. Also, compliance with criteria has to be controllable in practice, without incurring high additional costs. This section will discuss some aspects of the verification and implementation procedures of selected standards, followed by a section on costs.

5.1. Verification and monitoring

To make it possible that the bioenergy user or supplier can declare compliance of the end product with the sustainability requirements, certification of the primary product against a sustainability standard is needed. In addition, a traceability system – also called Chain of Custody (CoC) – needs to be established for the whole chain of production, processing and trade [21]. Three different CoC models can be distinguished: mass balance, track and trace and book and claim. See also NEN [21]. Certification against

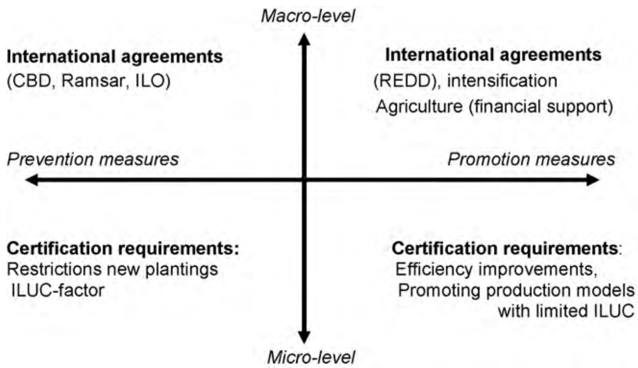

Fig. 9. Recommended combination of measures to avoid ILUC in a micro- and macro-context.

the requirements of a scheme is generally carried out by a certification body. Audits are carried out within a defined time frame. This may include consultation of external stakeholders. Audits include the assessment of the sustainability of the product and the CoC [21].

Table 13 shows a limited overview of developed assessment procedures for verification for a number of initiatives. More information on verification and monitoring procedures of standards can be found in Dam et al. [154]. Table 13 shows that various recently established initiatives (roundtables, NTA8080, ISCC) are still working on the establishment of their CoC and verification system. Also, differences are visible in e.g. whether external stakeholder consultation is required or in the type and number of CoC systems included in the standards. These different monitoring and verification requirements result, consequently, also in different levels of reliability between initiatives. Another factor that affects the reliability is the standard's elaboration of C&I: the more vague and more general the criteria, the more difficult they will be to enforce [119].

Various organizations have developed protocols for the harmonization of procedures of certification schemes. ISO (see also Section 2.2) has developed various Codes of Good Practices to set the minimum requirements for auditors and certification bodies. Examples are Guide 59 (Code of Good Practice for Standardization[11]), Guide 66[12] or ISO 19011, that sets criteria for Quality Management System Auditors or Environmental Management System Auditors [80]. *ISEAL Alliance* develops Codes of Good Practice for credible social and environmental standards systems. Amongst its members are FSC, Rainforest Alliance, SAI, BSI and RSB [155]. ISEAL Alliance [102] recommends that standards should take a more comprehensive approach on monitoring and evaluation: Clarity on goals and how they will be achieved should be (transparently) defined and agreed upon (see Fig. 10). These goals should be the backbone of the monitoring and evaluation system. Its derivatives (C&I), combined with ongoing data gathering and analysis, should contribute towards insight in ongoing progress and provide insight for further learning and improvement.

Thus, well-defined and unified motoring and verification assessment procedures are required to assure the controllability, and hence the reliability, of certification standards. This includes the controllability of indicators in the field. Further harmonization can be achieved by requiring compliance of internationally acknowledged protocols, as provided by ISO or ISEAL.

[11] ISO Guide 59 includes minimum requirements expected of a standards-setting body.

[12] ISO Guide 66 sets general requirements for bodies operating assessment and certification of enviromental management systems.

5.2. Costs

There are two kinds of costs associated with certification: direct and indirect. Direct costs are the costs of the certification assessment and audits. Indirect costs are costs related to the changes that may be needed in management planning and practices to conform to the certification standards [156].

Direct costs generally include the costs to cover an audit team to visit an operation, possibly including time for report writing or pre-audit consultation. There is usually an annual re-audit. Additional costs could include an annual certification/accreditation fee [157]. Some initiatives (e.g. Naturland, RSPO or IFOAM) also require an annual membership fee and/or a fee for logo use. Examples for annual membership fees are 3700 US$ for RSPO (discounts for smallholders are available) or 3800 $NZ for GlobalGAP [39].

Auditor charges are market prices and they vary between countries and certifiers [157]. Certification audit costs depend on the size and location of the farm, the total number of producers in the group, the distance between farms and logistical costs. Auditing costs are also related to the number of sustainability criteria included in the standard and the type of expertise required for verifying them. The variation in auditing costs is shown by cost indications from FSC [80] showing ranges from 0.05 €/ha per year (Sweden, 2×10^6 ha) and 0.79 €/ha per year (Norway, 4×10^3 ha).

Direct costs for certification (including CoC certification) varies substantially when the above mentioned parameters are altered (see Table 14). Also, costs (in €/ha per producer) can be substantially reduced for producers applying for certification through a group entity. Examples of initiatives that (aim to) apply group certification are FSC, SAN, CERTFOR Chile, IFOAM, NTA 8080, RSPO and GlobalGAP [21,76,118,158–161]. Also, local auditors should be used whenever possible to reduce travel expenses.

The costs for CoC certification are lower when volumes are traded in large batches instead of smaller volumes. Note that this may result in a preference for large-scale producers and traders [162]. The NGO *CEO* (see Section 2.4) is concerned that large-scale actors are far more able to face the administrative burden related to certification than small-scale producers [80]. UK-RTFO indicates that administrative costs were not large for most businesses in its first year of implementation, although small biofuel producers were affected proportionally more.

Concluding, the contribution of *direct* certification costs to total product costs (based on the assumed prices in Table 14) can remain limited, especially when group certification and logistics are considered.

It is difficult to specify the *indirect costs* of group certification, which are the management upgrades and investments needed to meet the certification standards. Indirect costs are influenced by the landowner's current level of practices and the required level of improvement [156]. According to Savcor [163], requirements on the extent of set-aside areas or yield reductions (see also Table 14) are main reasons for additional costs due to FSC certification. Examples of indicated indirect costs for FSC certification [80] range from 18.84 €/ha per year (Finland, 9×10^5 ha) to 1.81 €/ha per year (Norway, 4×10^3 ha). Other indications for additional costs found in literature are around 8% for FSC certification [164], 44% for meeting strict sustainability criteria for Eucalyptus produced in Brazil [165], 14% for willow production in Ukraine [165], 45–55% for organic sugar production in Brazil [166] and up to 65% for Indian food products to meet GlobalGAP criteria [167].

Note that the studies mentioned above do not include the possible economic benefits (e.g. maintenance of yields, soil restoration) that can be attained on the longer term when sustainability standards are complied with. Also, a complete valuation of environmental services and the attribution of these costs and benefits to all of its users are missing.

Table 13
Characteristics assessment procedures selected certification systems, based on [154]. • = Included, – = not included, and ○ not yet in place/in process, and [1]remarks.

Auditing process:	Certification biomass resource						Certification chain of custody						
	Assessment procedure						CoC			Assessment procedure			
	Field visits required	Reporting required		External stakeholder consultation required	Frequency auditing (no/year)	Validation certification contract (years)	Mass balance	Track and Trace	Book and Claim	Production controls required	Documentation required	Labeling required	Remarks/description
		By owner	By ac-countant										
EC-RED	○	○	○	○	○	○	•			○	○	○	
US-RFS													Not applicable
RTRS	•	•	–	•[1]	○	○	•	•	[2]	○	○	○[2]	[1] Defined as “to be important” [2] Book and Claim not ruled out. CoC: rules for control of claims and logos to be developed.
RSPO	•	•	–	•	1	5	•	•	•	•	•	○	
BSI	○	○	○	○	○	○	○	○	○	○	○	○	Status: standard development.
RSB	○	○	○	○	○	○	○	○	○	○	○	○	
ISCC	○[3]	•	○[3]	○[3]	1	○[3]	•	○	○	○[3]	•	•	[3] Verification process and guidelines for auditors to verify and gather data is ongoing.
NTA 8080	•	•	–	•	○	○	•[4]	•[4]	•[4]	○	○	•	[4] The three CoC models are all acceptable but in combination with different sustainability claims. For all counts that certain verification requirements have to be met.
UK-RTFO[5]	•	•	•[6]	○	1	1	•	– •[7]	–•[7]	•	•	–	[5] Guidelines for verification still under consultation. [6] Execution of assurance control includes performance of substantive testing. [7] Where an existing standard operates its own certifiable CoC should be used. Else mass balance should be used.
SAN standard	•	•	–	•	1	3	–	•	–	–/•[8]	–/•[8]	•	[8] Audit of CoC only implemented when there is an assumed risk for mixing of products (based on self-assessment)
FSC	•	•	–	•	1	<5	•	•	–	•	•	•	
Global-GAP	•	•	–	–	1[9]	1	–	•	–	•[10]	•[10]	•	[9] At least on an annual basis combined with unexpected visits. [10] Required: CoC chain linked with other approved systems
CERTFOR	•	•	•[11]	•	1	<5[12]	•	•	–	•	•	•	[11] Systems of sampling are responsibility of the certification body and audit team. [12] There is a review of the standard at least every 5 years

Table 14
Overview of indicated direct costs of direct certification with variation of key parameters that influence costs, based on [80,156,157,162]. *S = sample.

Options	S*1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Assumed product price (€/t)	100	100	100	100	100	100	100	100	100	100	100	100
Product certification												
External audit												
External audit (€)	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
Travel costs (€)	1000	1000	500	500	500	500	500	500	500	500	500	500
Total costs external audit (€)	8000	8000	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Internal audit												
Hourly cost (€/h)	35	35	35	35	35	35	35	35	35	35	35	35
Hours (number)	40	40	40	40	40	40	40	40	40	40	40	40
Year 1 (€)	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
Year 2–5 (€)	640	640	640	640	640	640	640	640	640	640	640	640
Annual audit cost (€/year)	792	792	792	792	792	792	792	792	792	792	792	792
Total cost per year (€/year)	2392	2392	2292	2292	2292	2292	2292	2292	2292	2292	2292	2292
Area size (ha)	1000	1000	1000	1000	1000	1000	1000	100	100	100	100	100
Number of producers	10	10	10	10	5	1	1	10	10	5	1	1
Costs (€/ha per producer)	0.24	0.24	0.23	0.23	0.46	2.29	2.29	2.29	2.29	4.58	22.92	22.92
Yield levels (ton/ha)	5	4* (* Required yield reduction as defined in standard)	5	2	5	5	2	5	2	5	5	2
Costs (€/t)	0.48	0.60	0.46	1.15	0.46	0.46	1.15	4.58	11.46	4.58	4.58	11.46
CoC certification												
Amount of product (t)	5000	4000	5000	2000	5000	5000	2000	500	200	500	500	200
Badge per import (t)	5000	4000	5000	2000	5000	5000	2000	500	200	500	500	200
Auditing days per badge	3	3	3	3	3	3	3	3	3	3	3	3
Cost per auditing day (€/day)	300	300	300	300	300	300	300	300	300	300	300	300
Costs (€/t)	0.18	0.23	0.18	0.45	0.18	0.18	0.45	1.80	4.50	1.80	1.80	4.50
Total costs (€/t)	0.66	0.82	0.64	1.60	0.64	0.64	1.60	6.38	15.96	6.38	6.38	15.96
Total product costs (€/t)	100.66	100.82	100.64	101.60	100.64	100.64	101.60	106.38	115.96	106.38	106.38	115.96
% From certification	0.7%	0.8%	0.6%	1.6%	0.6%	0.6%	1.6%	6.0%	13.8%	6.0%	6.0%	13.8%

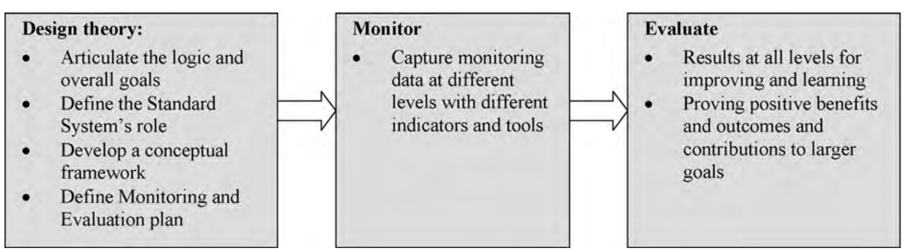

Fig. 10. Comprehensive approach for Monitoring and Evaluation based on [102].

Concluding, total costs for certification varies strongly depending on the region, area size and on the efficiency and type of management of the producer. Indirect costs are typically a factor 5–50 higher than the direct costs. The importance of creating a certification system that avoids excessive costs, particularly for small farmers in developing countries, is recognized [1]. Various existing standards have developed additional measures to minimize financial burdens for, especially, small farmers. Examples are UTZ [168] or SAN [169] that developed training modules to assist producers in yield improvements, market expertise and knowledge on management practices. SAN [169] also provides the possibility to farmers for stepwise improvement, linked to stricter criteria. This way, large costs are spread out over time and do not form an obstacle for certification.

6. Discussion and conclusions

During the last years, the socio-economic and environmental impacts and benefits of bioenergy production have been widely debated. Most concerns were, justifiably, pointed at the possible negative impacts from biofuels and its feedstock. Logically, most recent initiatives are focused on the sustainability of biofuels. Content-wise, most of these initiatives have mainly included environmental principles. The overview of 67 initiatives shows, however, that concerns in various parts of the world are focused on food security and on the socio-economic impacts of bioenergy production. Strikingly, these concerns are generally not included in the existing bioenergy initiatives. The overview shows as well that initiatives focused on solid biomass and bioenergy for heat and power are (still) limited although its feedstock may originate from the same feedstock as the biofuel, especially considering the expected development and deployment of 2nd generation biofuels. At the same time, the overview shows a strong proliferation of standards and, consequently, the risk for confusion in the market, abuse and "shopping" of standards.

A comparison is made of how sustainability principles are defined and quantified by various initiatives.

The overview shows that, despite ongoing efforts, a diversification between initiatives in methodologies and default values for calculating the GHG balance and carbon sinks continue to exist. These methodological differences are also visible in approaches to safeguard biodiversity conservation. Examples are the ambiguous interpretations of biodiversity-rich areas or the various approaches to map these areas in a region. Initiatives follow opposite approaches on how biodiversity should be protected: Excluding biodiversity-rich areas from an area, promoting biodiversity in an area or a combination of both. The overview shows that limited attention is given so far on the quantification of possible impacts of bioenergy production on biodiversity.

Standard's indicators for soil and water conservation focus mainly on the local ('micro') level and their system boundary is the production unit. Small changes in water use on a micro-level may, however, result into cumulative impacts on a meso- or macro-level. Activities outside the production unit may, vice versa, also affect water resources within the system boundary. This interaction between factors and impacts on micro- and meso-level is currently hardly addressed.

The ILO labour standards form a sound basis for a harmonized use of socio-economic principles on the well-being of employees. Measuring the social well-being of a community – as food security – is more complicated due to the variety of direct *and* indirect factors influencing social well-being in and outside the standard's system boundary.

The role of bioenergy production on ILUC is still very uncertain. Current initiatives have rarely captured impacts from ILUC in their standards. Available approaches include measures to avoid (direct) negative LUC impacts – mainly on GHG emissions and biodiversity – combined with promoting business models that demonstrate low risks of indirect effects. Measures focused on other impacts from ILUC, as food security or social well-being, are hardly included.

The overview also shows the limitation of these measurements when they are applied for bioenergy production alone. As food and feed crops do not face limitations in land use conversions, existing food areas can be easily diverted to bioenergy and new production to replace the lost food crops can still permissibly move into newly, unconverted land. A distinction between direct and indirect land use changes and between crops used for food, feed or energy (meaning fuel, heat and power) therefore no longer holds.

In spite of current limitations, the overview shows that certification has the potential to influence *direct*, *local* impacts related to environmental and social effects of *direct* bioenergy production with principles and criteria governing the particular lands and production processes used. This can be done – with the right monitoring and verification measures – against limited costs. Based on our overview, the following key recommendations can be given to come to a harmonized, efficient certification system to guarantee the sustainability of biomass and bioenergy:

- (Further) harmonization and international agreement on:
  a) Definitions; e.g. biodiversity-rich areas;
  b) Methodologies; e.g. conditions to safeguard biodiversity on various spatial levels;
  c) Performance indicators; e.g. required parameters for soil and water analysis;
  d) Harmonization of parameters and assumptions used in databases and models;
  e) Verification and monitoring procedures.
- *Harmonizing* a basic set of minimal sustainability requirements in *meta-standards* for the forestry, agriculture and bioenergy sector. Existing meta-standards (IFOAM, PEFC, and RSB) could take the lead in this process;
- *Linking* indicators on a micro, meso and macro level to monitor (cumulative) impacts related to bioenergy production. System boundaries per sustainability principle need to be defined in a standard to clarify the responsibility of the producer;
- (*Further*) *Methodological developments* to enhance the quantification and monitoring of sustainability principles. This includes the (further) development of:
  a) An approach to measure and monitor the possible contribution of biomass production to enhance (agro-) biodiversity on a local level;
  b) The quantification and monitoring of the social well-being of a community;
  c) Agro-economic equilibrium models to model ILUC as accurately as possible. This requires further understanding of the drivers of land use changes and its impacts on a regional level.
- Availability of reliable local, spatially explicit *data and maps* for the various regions and crops that can be used for bioenergy production; these data should be linked to national and international databases to improve monitoring on a meso and macro levels.

Certification can be one of the useful tools to stimulate sustainable land use on a local to regional level. However, considering the multiple spatial scales, this should be combined with additional measurements and tools on a regional, national and international level. This means addressing and weighing multiple sustainability criteria across multiple spatial scales and across development and deployment time scales. Interactions between criteria can strengthen (positive and negative) or fully negate its impact. Priorities and the allocation of socio-economic benefits and impacts to different stakeholder groups may differ as well. The following recommendations are given to improve the effectiveness of certification systems, in combination with other tools, to promote the sustainability of bioenergy:

- Addressing unwanted LUC requires first of all sustainable land use production and good governance, regardless of the end-use of the product. To a large extent, the decision on where and how to produce bioenergy crops should therefore be a land use management decision.
- Extend measures to effectively mitigate impacts from LUC to other lands and feedstock;
- Combine certification with positive incentives as tax incentives, direct subsidies or public investments. Combining these with absolute prohibitions or requirements and strong international agreements will encourage desired sustainable practices;
- Using proper regional analyses and designs of production models to identify suitable development pathways and beneficial strategies for all parties involved;

This challenge requires strong international cooperation, not limited to bioenergy producers, and should include all parties involved as the agricultural sector, livestock, energy and R&D sector.

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References

[1] van Dam J, Martin J, Faaij A, Jürgens I, Best G, Fritsche U. Overview of recent developments in sustainable biomass certification. Biomass and Bioenergy 2008;32(8):749–80.

[2] Wroughton L. Biofuels major driver of food price rise-World Bank. Reuters, Washington. Available at: http://www.alertnet.org/thenews/newsdesk/N28615016.htm; 2008.

[3] BBC Mundo. ONU: inflación en alimentos básicos. Available at: http://news.bbc.co.uk/hi/spanish/business/newsid_7281000/7281972.stm; 2008. Access date: March 6, 2009.

[4] Schubert RS, Schellnhuber HJ, Buchmann N, et al. Future bioenergy and sustainable land use. Berlin, Germany: German Advisory Council on Global Change WGBU; 2009. p. 366.

[5] Searchinger T, Heimlich R, Houghton R, et al. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 2008;319(5867):1238–40.

[6] Matthews JA, Tan H. Biofuels and indirect land use change effects: the debate continues. BIOFPR; 2009.

[7] Cornelissen S, Dehue B. Summary of approaches to accounting for indirect impacts of biofuel production. Utrecht, the Netherlands: Ecofys; 2009.

[8] RFA. The Gallagher review of the indirect effects of biofuel production. UK: Renewable Fuels Agency; 2008.

[9] FAO. The state of food and agriculture 2008: biofuels; prospects risks and opportunities. Rome, Italy: Food and Agriculture Organization of the United Nations; 2008.

[10] SCOPE. Biofuels: environmental consequences and interactions with changing land use. In: Proceedings of the scientific committee on problems of the environment (SCOPE) international biofuels project rapid assessment 22-25 September 2008; 2009.

[11] Tilman D, Socolow R, Foley JA, et al. Beneficial biofuels—the food, energy, and environment trilemma. Science 2009;325(5938):270–1.

[12] Fargione J, Hill J, Tilman D, et al. Land clearing and the biofuel carbon debt. Science 2008;319(5867):1235–8.

[13] van Dam J. Background document from: from the global efforts on certification of bioenergy towards an integrated approach based on sustainable land use planning. Utrecht, the Netherlands: Copernicus Institute, Utrecht University; 2010.

[14] IEA-OECD. Biofuels for transport: an international perspective. Paris: International Energy Agency in collaboration with Organization for Economic Cooperation and Development; 2005.

[15] Peterson J. Energy production with agricultural biomass: environmental implications and analytical challenges. Copenhagen, Denmark: European Environmental Agency; 2008.

[16] European Commission. Proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, COM (2008) 19 final. Commission of the European Communities: Brussels; 2008. 61 p.

[17] Lammers E, Godfroij P. Personal communication with Ella Lammers and Per Godfroij (SenterNovem) on status developing sustainability criteria for biomass, biofuels, electricity and heating in the Netherlands. 13 March 2009, Utrecht, the Netherlands; 2009

[18] EC. Report from the Commission to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling. SEC (2010). European Commission: Brussels; 2010. p. 65–66.

[19] Council of the European Union. Sustainability criteria for biomass—information from Belgium, the Netherlands and Luxembourg, ENV 901–ENER 447. Brussels; 2009.

[20] Cramer J, Wissema E, de Bruijne M, et al. Testing framework for sustainable biomass. Final report from the project group "Sustainable production of biomass". Project group "Sustainable production of biomass": The Hague, the Netherlands; 2007. 72 p.

[21] NEN. Sustainability criteria for biomass for energy purposes NTA 8080: 200_EN. Delft, the Netherlands: Nederlands Normalisatie Instituut NEN; 2009.

[22] CDB. First recommendations CDB. Available at: http://www.corbey.nl/index.asp?page_id=139; 2009. Access date: 12 December 2009.

[23] RTFO. About the RTFO and RTFO targets. Available at: http://www.renewablefuelsagency.org/aboutthertfo/rtfotargets.cfm; 2009. Access date: 14 July 2009.

[24] RFA. Carbon and sustainability reporting within the renewable transport fuel obligation, technical guidance Part 1, version 2.0. East Sussex: Renewable Fuels Agency; 2009.

[25] Martikainen A, von Bothmer P. Country report Germany of different criteria for sustainability and certification of biomass and solid, liquid and gaseous biofuels, WP 4.3. Solutions for biomass fuel market barriers and raw material availability—IEE/07/777/SI2.499477. EUBIONET IIII. Fachagentur Nachwachsende Rohstoffe: Gülzow, Germany; 2009.

[26] Swiss Federation. Switzerland—recent energy developments. For submission at the SLT Meeting of 10–11 March 2008 IEA; 2008. 2 p.

[27] Ryckmans Y. André N. Novel Certification procedure for the sustainable import of wood pellets to power plants in Belgium. Available at: http://www.laborelec.com/pages_files/Paper-Berlin%20ETA%20EUR%20Biomass%20Conf-Market&sustainability-2007.pdf; 2007. Access date: 27 May 2009.

[28] Ryckmans Y, Marchal D, André N. Energy balance and greenhouse gas emissions of the whole supply chain for the import of wood pellets to power plants in Belgium. Gembloux, Belgium: Electrabel/Laborelec, CRAGx, SGS Environmental Services; 2006, 5 p..

[29] EPA. EPA Lifecycle analysis of greenhouse gas emissions from renewable fuels. Office of Transportation and Air Quality, EPA-420-F-10-006, February 2010. Environmental Protection Agency: USA; 2010.

[30] Borrell B. Massachusetts pushes waste-based biofuels, holds off on corn, algae, and switchgrass. Available at: http://www.scientificamerican.com/blog/60-second-science/post.cfm?id=massachusetts-pushes-waste-based-bi-2009-08-20; 2009. Access date: 15 November 2009.

[31] Sperling D, Yeh S. Low carbon fuel standards. Issues in Science and Technology, p. 57–66; 2009.

[32] Sylvestre P. Personal e-mail communication with P. Sylvestre, Strategic Policy and Emerging Issues, on 15 February 2010 on ongoing work in the development of sustainability guidelines for bioenergy in Canada. Energy and Transportation Directorate, Environment Canada: Montreal, Canada; 2010.

[33] BIOPACT. An in-depth look at Brazil's Social Fuel Seal, 23 March 2007. Available at: http://news.mongabay.com/bioenergy/2007/03/in-depth-look-at-brazils-social-fuel.html; 2007. Access date: 8 April 2009.

[34] Jumbe CBL, Msiska FBM, Madjera M. Biofuels development in sub-Saharan Africa: are the policies conductive? Energy Policy 2009;37(11):4980–6.

[35] Esterhuizen D. Biofuels annual republic of South Africa. Available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/General%20Report_Pretoria_South%20Africa%20-%20Republic%20of_5-28-2009.pdf; 2009.

[36] Conselho de Ministros da república de Moçambique. Publicação oficial da república de Moçambique, Política e Estratégia de Biocobustíveis; 2009.

[37] USAID. Biofuels in Asia: an analysis of sustainability options. United States Agency for International Development Asia; 2009.

[38] JORA. Poster presentation on "Outline of Biomass Mark". Third Biomass—Asia workshop. Tokyo, Japan; 2006.

[39] SKM. Consumer information on biofuel sustainability. Sinclair Knight Merz commissioned by Energy Efficiency and Conservation Authority: Wellington, New Zealand; 2008.

[40] ISO. ISO/PC "Sustainability criteria for bioenergy" Berlin Meeting, 08/09 June 2009, Recommendations from the preliminary meeting. In: Preliminary Meeting, 08/09 June 2009. Berlin, Germany; 2009.

[41] Costenoble O. *Presentation on 'Towards European Sustainability Criteria for Biomass?' from a NEN perspective.* In: NEN Informatiebijeenkomst duurzaamheidscriteria voor biomassa. Delft, the Netherlands; 2008.

[42] CEN/TC 383. CEN/TC 383 sustainably produced biomass for energy applications, version of: 30/03/2009. The Netherlands; 2009.

[43] Dakhorst J. E-mail communication J. Dakhorst (NEN—Nederlands Normalisatie-instituut) on feedback CEN/TC 383 meeting from June 2009. Delft, the Netherlands; 2009.

[44] GBEP. The Global Bioenergy Partnership, three page leaflet. Available at: http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/GBEP_-standard_material/GBEP_Background_note_240709.pdf; 2009. Access date: 1 September 2009.

[45] Brieskorn R. Meeting on 18 January 2010 on proposed set of C&I from GBEP and planned activities. The Hague: Ministry of VROM; 2010.

[46] RSB. Indicators of compliance for the RSB principles & criteria—RSB reference code: [RSB-IND-20-001 (version 1.0)]. Roundtable on Sustainable Biofuels: Lausanne; 2009.

[47] RSB. The roundtable on sustainable biofuels. Available at: http://cgse.epfl.ch/page65660-en.html; 2009. Access date: 26 March 2009.

[48] IDB. IDB biofuels sustainability scorecard. Available at: http://www.iadb.org/scorecard/; 2008. Access date: 2 April 2009.

[49] GRI. Global reporting initiative, reporting frameworks. Available at: http://www.globalreporting.org/ReportingFramework/ReportingFramework-Downloads/#languages; 2009. Access date: 12 December 2009.

[50] UN-Energy. Sustainable bioenergy: a framework for decision-makers. Available at: http://www.fao.org/docrep/010/a1094e/a1094e00.htm; 2007. UN-Energy, collaborative framework for all UN-bodies.

[51] UNEP. 2nd Joint International Workshop on Bioenergy, Biodiversity Mapping and Degraded Lands held from July 7–8, 2009 at UNEP DTIE Office in Paris, France. Available at: www.bioenergywiki.net/index.php/2nd_Joint_International_Workshop_Mapping. Prepared by Oeko-Institut and UNEP: Paris; 2009.

[52] UNEP, 2007. Working group on developing sustainability criteria and standards for the cultivation of biomass used for biofuels, working paper: compilations of existing certification schemes, policy measures, ongoing initiatives and crops used for bioenergy. United Nations Environment Programme, DaimlerChrysler, and the Ministry of Nutrition and Rural Affairs of Baden Württemberg.

[53] Ecologo. Biomass certification discussion document. Available at: http://www.ecologo.org/common/assets//(C)%20Biomass%20CDD%20for%20CCD-003%20Rev%202008.pdf; 2009. Access date: 21 April 2009.

[54] Green-E. Green-E energy national standard version 1.6. Available at: http://www.green-e.org/docs/energy/Appendix%20D_Green-e%20Energy%20National%20Standard.pdf; 2008.

[55] Fehrenbach H, Giegrich J, Reinhardt G, et al. Criteria for a Sustainable Use of Bioenergy on a Global Scale, research report 206 41 112, UBA-FB 001176/E. Institut für Energie- und Umweltforschung, FSC Arbeitsgruppe Deutschland and Germanwatch on behalf of the Federal Environment Agency: Heidelberg; 2008. 245 p.

[56] SMK. Certificatieschema Groene Electriciteit MK.67. Available at: http://www.smk.nl/files/categories/5/546/GE_NL4.pdf; 2009.

[57] EUGENE. Information about EUGENE standard. Available at: http://www.eu-genestandard.org/; 2009. Access date: 12 December 2009.

[58] Hartkamp R, Vlot I, Geene K. 2nd concept report Cramer criteria Benchmark of Green Gold Label and Laborelec (on basis of own agro standards). The Hague: SMK; 2009.

[59] Drax. Sustainability policy for biomass. Available at: http://www.draxgroup.plc.uk/corporate_responsibility/environment/biomass_sustainability_policy/; 2009. Access date: 23 November 2009.

[60] GGL. Introduction on the Green Gold Label Programme. Available at: http://certification.controlunion.com/certification/program/Program.aspx?Program_ID=19; 2009. Access date: 1st of June 2009.

[61] ISCC. Brochure on "Taking off. The certification of biomass and bioenergy: International sustainability and carbon certification". Méo Corporate development GmbH. Cologne, Germany. Available at: http://www.iscc-project.org/e711/element712/090218_ISCCBro_en_eng.pdf; 2009.

[62] BMELV. Biomasse nur noch aus nachhaltigem Anbau: Staatssekretärin Klöckner stellt erstes europäisches Zertifizierungssystem vor. Available at: http://www.bmelv.de/cln_172/sid_E040C78F11C4D7C3AD5F569BDF14D6BB/SharedDocs/Pressemitteilungen/2010/013-KL-Zertifizierungssystem-ISCC-Biomasse.html; 2010.

[63] Greenergy. RTFO sustainable biofuel met-standard: Greenergy interpretation for Brazilian Sugarcane. Prepared by Proforest for Greenergy International: London; 2008.

[64] SEKAB. SEKAB Sustainability Criteria. Available at: http://www.sustainable-ethanolinitiative.com/default.asp?id=1087; 2009.

[65] ENERS. Project of labels for sustainable biofuels. Available at: http://www.biofuels-platform.ch/en/label/index.php; 2009. Access date: 12 December 2009.

[66] NBB. NBB position on sustainable biodiesel. Jefferson City, USA: National Biodiesel Board; 2008.

[67] NBB. Guiding principles for biodiesel sustainability. Available at: http://www.biodieselsustainability.com/principles.html; 2008. Access date: 14 April 2009.

[68] Nordic Ecolabelling. Swan-labeling of biofuel pellets, version 2.0, 13 December 2007-31 December 2012. Nordic Ecolabelling: Stockholm, Oslo, Helsingfors, Reykjavik, Charlottenlund; 2007.

[69] Nordic Ecolabelling. SWAN labeling of fuels—Version 1.0 (25 June 2008–30 June 2010). Nordic Ecolabelling: based in Charlottenlund, Oslo, Reykjavik, Stockholm and Helsingfors; 2008.

[70] SBA. Sustainable biodiesel alliance introduces sustainability standards for the US biodiesel industry. Available at: http://www.pr-inside.com/sustainable-biodiesel-alliance-introduces-sustaina-r763649.htm; 2008. Access date: August 19, 2008.

[71] CSBP. Council on sustainable biomass production. Available at: http://www.csbp.org/?q=node/1; 2008. Access date: 14 April 2009.

[72] WWF. WWF position paper on bioenergy. World Wildlife Fund. Available at: http://assets.panda.org/downloads/wwf_position_paper_on_bioenergy_291107.pdf; 2008.

[73] CEO. Paving the way for agrofuels, EU policy sustainability criteria and climate calculations. Amsterdam: Corporate Europe Observatory; 2007, 60 p..

[74] Lewandowski I, Faaij A. Steps towards the development of a certification system for sustainable bio-energy trade. Biomass and Bioenergy 2006;30(2):83–104.

[75] Kaphengst T, Ma MS, Schleger S. At a tipping point? How the debate on biofuel standards sparks innovative ideas for the general future of standardization and certification schemes. Journal of Cleaner Production 2009;17(1):S99–101.

[76] FSC. FSC International Standard. FSC principles and criteria for Forest Stewardship FSC-STD-01-001 (version 4-0) EN. Bonn, Germany: Forest Stewardship Council A.C.; 1996.

[77] PEFC. Information on members and schemes. Available at: http://www.pefc.org/internet/html/members_schemes/4_1120_59.htm; 2009. Access date: 7 July 2009.

[78] PEFC Watch. PEFC Watch. Available at: http://www.pefcwatch.org/; 2009. Access date: 12 December 2009.

[79] Delaney G. Environmentalists doubt green forestry claim. Chronicle Herald Canada. Available at: http://thechronicleherald.ca/NovaScotia/1155961.html; 2009.

[80] BTG. Sustainability criteria and Certification systems for biomass production, final report, project no. 1386. BTG Biomass Technology Group BV, prepared for DG TREN European Commission: Enschede, the Netherlands; 2008.

[81] MCFPE. Information on ministerial conference on protection of forests in Europe. Available at: http://www.mcpfe.org/www-mcpfe/; 2009. Access date: 17 July 2009.

[82] ITTO. ATO/ITTO principles, criteria and indicators for the sustainable management of African natural tropical forests, ITTO Policy Development Series No. 14. African Timber Organization and International Tropical Timber Organization: Yokohama; 2003.

[83] ITTO. Revised ITTO criteria and indicators for the sustainable management of tropical forests including reporting format, ITTO Policy Development Series No. 15. International Tropical Timber Organization: Yokohama; 2005.

[84] CCBS. Terms of reference and guidance document for validation using CCBS standards. Climate, Community and Biodiversity Alliance: Arlington, USA. Available at: http://www.climate-standards.org/standards/using.html; 2005.

[85] IFOAM. Program 2011. Available at: http://www.ifoam.org/about_ifoam/pdfs/Program_2011_web.pdf; 2008. Access date: 16 June 2009.

[86] EC. Legislation organic farming European Commission. Available at: http://ec.europa.eu/agriculture/organic/eu-policy/legislation_en; 2009. Access date: 7 October 2009.

[87] SAN. SAN addendum—additional SAN criteria for oil palm, sugarcane, soy peanuts and sunflower farms. San José, Costa Rica: Sustainable Agriculture Network; 2009.

[88] FLO. Website fairtrade labelling organizations international. Available at: http://www.fairtrade.net/home.html; 2009. Access date: 7 May 2009.

[89] FLO. Generic fairtrade standards for small producers' organizations, current version: 01 January 2009. Fairtrade Labelling Organizations International (FLO): Bonn, Germany. Available at: http://www.fairtrade.net/fileadmin/user_upload/content/Jan_2009_EN_Generic_Fairtrade_Standards_SPO.pdf; 2009.

[90] FLO. Generic fairtrade trade standards, current version: 16.02.2009. Fairtrade labelling organizations international: Bonn, Germany. Available at: http://www.fairtrade.net/fileadmin/user_upload/content/GTS_Feb09_EN.pdf; 2009.

[91] IFOAM. About the international federation of organic agriculture movements (IFOAM). Available at: http://www.ifoam.org/about_ifoam/index.html; 2009. Access date: 16 June 2009.

[92] Ökolandbouw. Database on agricultural standards and directives. Available at: http://www.oekoregelungen.de/; 2009. Access date: 14 October 2009.

[93] RSPO. Current projects roundtable on sustainable palm oil. Available at: http://www.rspo.org/projects_list.aspx?catid=2&ddlID=2; 2009. Access date: 9 March 2009.

[94] RSPO. GHG emissions from palm oil production. Literature review and proposals for amendments of RSPO Principles & Criteria. Draft for public consultation, 10 July 2009. Greenhouse Gas Working Group RSPO. Available at: http://www.rspo.org/resource_centre/GHG-emissions-from-palm-oil-DraftPublicCons.pdf; 2009.

[95] Damodaran R. RSPO delays greenhouse gas criteria for industry, see also: http://www.btimes.com.my/Current_News/BTIMES/articles/rspo7/Article/index_html; 2009 in Business Time.

[96] RTRS. Draft RTRS principles and criteria: third public consultation document, reference: DG4-OUT-02-ENG. The RTRS Principles, Criteria and Verification Working Group (DG) as an output of their fourth meeting from 10–13 October; 2008.

[97] RTRS. Website roundtable on responsible soy. http://www.responsible-soy.org/; 2009. Access date: 13 March 2009.

[98] BSI. BSI public consultation standard version 2: better sugarcane initiative principles and criteria. November 10 2009. Better Sugarcane Initiative Ltd: London; 2009.

[99] BSI. The better sugarcane initiative (BSI). Available at: http://www.bettersugarcane.org/; 2009. Access date: 18 March 2009.

[100] ISO. ISO about social responsibility. Available at: http://isotc.iso.org/livelink/livelink/fetch/2000/2122/830949/3934883/3935096/07_gen_info/about.html; 2009. Access date: October 13, 2009.

[101] Dam J, van Faaij APC, Gustavvson L, et al. A unified methodology and tool to evaluate greenhouse gas balances and cost-effectiveness of various biomass energy systems. Journal of Climatic Change 2009 [in review].

[102] Russillo A. State of the Art in measuring the impacts of social and environmental standard systems, R081—Public Summary. Report prepared by Liseed Consulting for ISEAL Alliance: London, UK; 2009.

[103] Hamelinck C, Koop K, Croezen H, et al. Technical specification: greenhouse gas calculator for biofuels, version 2.1 B, PBIONL062632/PBIONL081307. Available at: http://www.senternovem.nl/mmfiles/Technicalspecificationv2.1b20080813_tcm24-280269.pdf. Ecofys, CE, commissioned by SenterNovem: Utrecht, Delft; 2008.

[104] SenterNovem. CO2 tool: Bepaling broeikasgasemissies bij de productie van elektriciteit, warmte en transportbrandstoffen uit biomassa. Available at: http://www.senternovem.nl/duurzameenergie/publicaties/publicaties_bio-energie/co2_tool.asp. Access date: 11 march 2009.

[105] Bauen A, Watson P, Howes J. Carbon reporting with the renewable transport fuel obligation—methodology. London: E4Tech in consultation with the Department for Transport; 2007.

[106] GBEP Task Force. The global bioenergy partnership GHG methodologies task force—draft proposal for framework. In: 4th Meeting of the GBEP Task Force on Sustainability. Heidelberg, Germany: The Global Bioenergy Partnership; 2009.

[107] RSB. Roundtable on sustainable biofuels. The working group on Greenhouse Gases—debated issues by topic. Available at: http://cgse.epfl.ch/page68127.html; 2009. Access date: 23 March 2009.

[108] IEA Bioenergy Task 38. Examples of greenhouse gas modeling tools. Available at: http://www.ieabioenergy-task38.org/softwaretools/; 2010. Access date: 4 January 2010.

[109] GHGP. The greenhouse gas protocol initiative. Available at: http://www.ghgprotocol.org/about-ghgp; 2010. Access date: 4 January 2010.

[110] JRC. Data on pathways for RED Directive - Input data BIO 181108. Available at: http://ies.jrc.ec.europa.eu/WTW; 2009.

[111] MVO. VS publiceert duurzaamheidscriteria biobrandstoffen. Available at: http://www.mvo.nl/Publicaties/NieuwsbriefBiobrandstoffen/No03dd09022010/tabid/1486/language/nl-NL/Default.aspx; 2010. Access date: 09.02.2010.

[112] Ching OT. Joint plan to file case against EU palm oil directive. Available at: http://www.btimes.com.my/Current_News/BTIMES/articles/lyc/Article/; 2009. Access date: 10 December 2009.
[113] Veldkamp E, Becker A, Schwendenmann L, et al. Substantial labile carbon stocks and microbial activity in deeply weathered soils below a tropical wet forest. Global Change Biology 2003;(9):1171–84.
[114] Dam J, van, Faaij A, Hilbert J, et al. Large-scale bioenergy production from soybeans and switchgrass in Argentina, Part B. Environmental and socio-economic impacts on a regional level. Renewable and Sustainable Energy Reviews 2009;(13):1679–709.
[115] Hoefnagels R, Smeets EMW, Faaij APC. A greenhouse gas footprints of different biofuel production systems. Renewable and Sustainable Energy Reviews 2010;14(7):1661–94.
[116] Naturland. Naturland standards on production. Gräfelring, Germany: Naturland - Registered Association for Organic Agriculture; 2008.
[117] SAN. Sustainable agriculture standard: sustainable agriculture network. San José, Costa Rica: Sustainable Agriculture Network; 2009.
[118] RSPO. RSPO Principles and Criteria for Sustainable Oil Production including Indicators and Guidance. Kuala Lumpur, Malaysia: Roundtable on Sustainable Palm Oil; 2007, 53 p..
[119] Searchinger T. Government Policies & Drivers of World Biofuels, Sustainability Criteria, Certification Proposals & their limitations. In: Biofuels: environmental consequences and interactions with changing land use. Proceedings of the scientific committee on problems of the environment (SCOPE) International Biofuels Project Rapid Assessment 22-25 September 2008; 2008.
[120] HCV Resource Network; 2007. HCV toolkits available at: http://www.hcvnetwork.org/practical-support/the-hcv-toolkit-global-home. Access date: 27 June 2009.
[121] Kuijk M, Putz FE, Zagt R. Effects of forest certification on biodiversity. Wageningen, The Netherlands: Tropenbos International; 2009.
[122] Dornburg V, Vuuren D, van Langeveld H, et al. Bioenergy revisited: key factors in global potentials of bioenergy. Journal of Energy and Environmental Science 2010. doi:10.1039/B922422J.
[123] PBL. Monitoring macro-impacts of bioenergy. Bilthoven, the Netherlands: PBL, Netherlands Environmental Assessment Agency; 2009.
[124] Fritsche UR, Hennenberg KJ, Hermann A, et al. Development of strategies and sustainability standards for the certification of biomass for international trade. Sustainable bioenergy: current status and outlook: summary of recent results from the research project. In: Environmental research plan of the federal ministry for environment, nature protection and nuclear safety interim report FKZ 37 07 93 100. Öko-Institut and IFEU: Darmstadt, Heidelberg; 2009.
[125] ITS. Evaluation and assessment of the Cerflor–Brazilian forest certification scheme against the requirements of the PEFC Council, final report, prepared for the PEFC Council by ITS Global. ITS Global: Melbourne, Australia; 2005.
[126] RSB. RSB Version 1.0 food security guidelines, RSB-GUI-20-009 (version 1.0) RSB food security guidelines 12/11/09. Roundtable on sustainable biofuels: Lausanne, Switzerland; 2009.
[127] RFA. RFA guidance for verifiers renewable fuels agency version 1.0 May 2009. Renewable Fuels Agency: East Sussex; 2009.
[128] UN. The universal declaration of human rights. Available at: http://www.un.org/en/documents/udhr/; 1948. Access date: 9 November 2009.
[129] UN. United Nations declaration on the rights of indigenous peoples. Available at: http://www.un.org/esa/socdev/unpfii/en/drip.html; 2007.
[130] ILO. Information about ILO and the international labour conference. Available at: http://www.ilo.org/global/What_we_do/Officialmeetings/ilc/AbouttheILC/langen/index.htm; 2009. Access date: 9 November 2009.
[131] Nußberger A. In: Social Security as a Human Right, Riedel E, editors. Evaluating the ILO's approach to standard-setting and monitoring in the field of social security. Berlin, Heidelberg: Springer; 2007.
[132] PEFC. Basis for certification schemes and their implementation—Annex 3. Geneva, Switzerland: Programme for the Endorsement of Forest Certification schemes; 2007, 10 p..
[133] FAO. Bioenergy and Food Security Criteria and Indicators (BEFSCI) project; 2010. http://www.fao.org/bioenergy/foodsecurity/befsci/en/. Access date: 18 January 2010.
[134] RSB. RSB Version 1.0 Food Security Guidelines, RSB-GUI-20-009 (version 1.0) RSB Food Security Guidelines 12/11/09 Roundtable on Sustainable Biofuels: Lausanne, Switzerland; 2009.
[135] Fürst M, Casale J, Wilhelm B. Recommendations for inspections of social standards: tools and methodologies for implementation of chapter 8 on Social Justice of the IFOAM Basic Standards. Bonn, Germany: IFOAM International Federation of Organic Agriculture Movements, Naturland Association; 2005.
[136] Farrell A. Presentation on "The Low Carbon Fuel Standard and land use change". In: WSPA Lifecycle Analysis Collaborative. Sacramento, CA: Energy and Resources Group, UC Berkeley; 2008.
[137] Woods J. Bioenergy and indirect land use change. Available at: http://www.ieabioenergy.com/DocSet.aspx?id=6214; 2009. In: Workshop on the Impact of Indirect Land Use Change (ILUC). Rotterdam, The Netherlands: IEA ExCo.
[138] FAO. How to feed the world in 2050?. Rome: Food and Agricultural Organization of the United Nations; 2009.
[139] Ros JPM, Overmars KP, Stehfest E, et al. Identifying the indirect effects of bioenergy production. Bilthoven, the Netherlands: Netherlands Environmental Assessment Agency (PBL); 2010.
[140] IEA Bioenergy. In: Bioenergy—the impact of indirect land use change. Summary and conclusions from the IEA Bioenergy ExCo63 Workshop; 2009.
[141] Tipper R, Hutchison C, Brander M. A practical approach for policies to address GHG emissions from indirect land use change associated with biofuels, technical paper TP-080212-A. Ecometrica, reviewed by Imperial College, commissioned by Greenergy International: London; 2009.
[142] Kretschmer B, Peterson S. Integrating Bioenergy into computable general equilibrium models—a survey. Energy Economics 2009. doi:10.1016/eneco.2009.09.011.
[143] Dunham S. Presentation on EISA renewable fuels provisions & transportation fuels GHG lifecycle analysis. Washington, DC: Transportation and Climate Division, U.S. Environmental Protection Agency; 2008.
[144] GTAP. GTAP Environmental and Energy Research. Available at: https://www.gtap.agecon.purdue.edu/models/energy/default.asp; 2002. Access date: 17 November 2009.
[145] IIASA. Biofuels and food security: implications of an accelerated biofuels production. Summary of the OFID study prepared by IIASA. International Institute for Applied Systems Analysis: Vienna, Austria; 2009.
[146] Edwards R, Szekeres S, Neuwahl F, et al. Biofuels in the European context: facts and uncertainties. Petten, The Netherlands: Joint Research Centre, European Commission; 2008.
[147] EPA. Emissions from land use change due to increased biofuel production: Satellite imagery and emissions factor analysis. ICF International, Environmental Protection Agency; 2009.
[148] Smeets EMW, Faaij APC, Lewandowski I. A quickscan of global bioenergy potentials to 2050. Biomass and Bioenergy 2007;33(1).
[149] Hoogwijk M, et al. Potential of biomass energy out to 2100, for four IPCC SRES Scenarios. Biomass and Bioenergy 2005;29(4):225–57.
[150] de Wit M, Faaij A. European biomass resource potential and costs. Biomass and Bioenergy 2010;34(2):188–202.
[151] SustainableBusiness.com. Massachusetts Bill Exempts Cellulosic Ethanol From State Taxes. Available at: http://wwww.sustainablebusiness.com/index.cfm/go/news.display/id/16566; 2008. Access date: 13 August 2008.
[152] RFA. Renewable fuels agency 2008/09 Annual Report to Parliament on the Renewable Transport Fuel Obligation. Presented to Parliament pursuant to The Renewable Transport Fuel Obligations Order 2007 (SI 2007 no 3072). Renewable Fuels Agency: London; 2010.
[153] CBD. Maak landbouw deel van de oplossing!In: Advies: Indirect Land Use Change (ILUC). THe Hague, the Netherlands: Commissie Duurzaamheidsvraagstukken (CBD); 2009.
[154] Dam J, van Londo M, et al. WP 3: Technical assistance for an evaluation of international schemes to promote biomass sustainability. In the context of the Multiple Framework Services TREN/A2/143-2007. ECN Energy Research centre of the Netherlands, Copernicus Institute, Utrecht University, Forest & Landscape Denmark, University of Copenhagen, COWI A/S, ControlUnion Certifications; 2009.
[155] ISEAL Alliance. Introduction and Information on full and affiliate members of the ISEAL Alliance. Available at: http://www.isealalliance.org/index.cfm?nodeid=1; 2009. Access date: 12 December 2009.
[156] Smith W. Group certification options: costs and benefits. New York: SmartWood Program of Rainforest Alliance; 2002.
[157] Robinson D. Personal e-mail communication with Dawn Robinson from Proforest on ongoing work in RTRS. Oxford, UK; 2009.
[158] CERTFOR. Lista de verificación de manejo forestal sustentable, version 02/2007 PS-02-03. CERTFORCHILE: Santiago, Chile. Available at: http://www.certfor.org/estandares_mfsp.html; 2007.
[159] Rainforest Alliance. News and introduction on Rainforest Alliance. Available at: http://www.rainforest-alliance.org/index.cfm; 2009. Access date: 25 June 2009.
[160] IFOAM. The IFOAM Norms for organic production and processing version 2005 including IFOAM Basic Standards and IFOAM Accreditation Criteria. Bonn, Germany: IFOAM; 2009, 127 p..
[161] GlobalGAP. GlobalG.A.P (EurepGAP) General Regulations Integrated Farm Assurance Version 3. 0-2_Sep07. Part 1 - General information. GlobalG. A. P.. Köln, Germany: FoodPlus GmbH; 2007.
[162] Beekes M. Personal e-mail communication with Mark Beekes, account manager KEMA, on the implementation of NTA 8080 in the Netherlands with an emphasis on costs and measurement of indicators. Utrecht; 2009.
[163] Savcor. Effectiveness and efficiency of FSC and PEFC Forest certification on pilot areas in Nordic countries, final report. Available at: http://www.skog.no/skog_data/Attachments/284/NSF_Report_final.pdf; 2005. Savcor Indufor Oy: Helsinki, Finland.
[164] Malmi I. Certification costs in private forestry (summary). Available at: http://honeybee.helsinki.fi/mmeko/OPINNOT/opinnayte/Malmi.pdf; 2000. Department of Forest Ecology, University of Helsinki: Helsinki.
[165] Smeets E, Faaij A, Lewandowski I. The impact sustainability criteria on the costs and potentials of bioenergy production. An exploration of the impact of the implementation of sustainability criteria on the costs and potential of bioenergy production applied for case studies in Brazil and Ukraine. Report NWS-E-2005-6. Copernicus Institute: Utrecht, the Netherlands; 2005.
[166] Macedo editor. Sugar cane's energy. Twelve studies on Brazilian sugar cane agribusiness and its sustainability. UNICA; 2005. 237 p.
[167] FICCI. High cost of standard compliance making exports to EU difficult: FICCI survey. Available at: www.ficci.com/press/highcost-20march.doc; 2006.

[168] UTZ Certified. Utz Certified - Impact in coffee growing. Available at: http://consumer.utzcertified.org/index.php?pageID=218; 2009. Access date: 2 December 2009.
[169] SAN. Farm Certification Policy: Sustainable Agriculture Network. San José, Costa Rica: Sustainable Agriculture Network; 2009.
[170] EPA. EPA Lifecycle analysis of greenhouse gas emissions from renewable fuels EPA-420-F-09-024. Available at: http://www.epa.gov/oms/renewablefuels/420f09024.htm; 2009.
[171] RFA. Carbon and sustainability reporting within the renewable transport fuel obligation. Technical guidance part two carbon reporting–default values and fuel chains. Version 2.0 March 2009. Renewable Fuels Agency; 2009.
[172] Edwards K. Co-product Allocation in Life Cycle Assessment: A Case Study Extended Abstract 2009-645-AWMA. Trinity Consultants: Stillwater, USA; 2009.
[173] Bottmer P. Personal communication with Philipp Bottmer from FNR on progress ISCC. Gülzow, Germany; 2009.
[174] GGL. GGLS2 – Agricultural Source Criteria – Green Gold Label Program, version 2005.1. Available at: http://certification.controlunion.com/certification/program/Program.aspx?Program_ID=19; 2005. Green Gold Label Program. 2 p.
[175] SFI. Sustainable forestry initiative 2005–2009 standard. Washington DC, USA: Sustainable Forestry Initiative; 2004.
[176] NNP. Natura 2000 networking programme. Available at: http://www.natura.org/about.html; 2007. Access date: 15 April 2009.
[177] WWF. WWF Ecoregions, Global 200. Available at: http://www.worldwildlife.org/science/ecoregions/global200.html; 2009. Access date: 18 October 2009.
[178] Birdlife International. Important bird areas. Available at: http://www.birdlife.org/action/science/sowb/state/24.html; 2008. Access date: 19 October 2009.
[179] IBAT. IBAT tool. Available at: http://www.ibatforbusiness.org/; 2009. Access date: 18 October 2009.
[180] GlobalGAP. GlobapG.A.P. (EurepGap) Control Points and Compliance Criteria Integrated Farm Assurance: All Farms Base, English version V3.0-2 Sep07; 2007. GlobalG.A.P. Köln, Germany.
[181] GlobalGAP. GlobapG.A.P. (EurepGap) Control Points and Compliance Criteria Integrated Farm Assurance: Crops Base, English version V3.0-3_Feb.09. GlobalG.A.P. Köln, Germany; 2009.
[182] GlobalGAP (2007), GlobapG.A.P. (EurepGap) control points and compliance criteria integrated farm assurance: Combinable Crops, English version V3.0-2 Sep07. GlobalG.A.P: Köln, Germany.
[183] GGL. GGLS5 - forest management criteria, green gold label program version 2005.2. Green Gold Label Program; 2005. 4 p.
[184] GGL. GGLS7–Conservation Stewardship Criteria, version 2008.1. Available at: http://certification.controlunion.com/certification/program/Program.aspx?Program_ID=19; 2008. Green Gold Label Program, 2 p.
[185] Laboralec. Form D and F Procedure certification Biomass Laborelec; 2008. http://www.laborelec.com/content/EN/Renewables-and-biomass_p83.
[186] SBA. Sustainable Biodiesel Alliance: Principles and baseline practices for Sustainability, Version 1.0. Sustainable Biodiesel Alliance: Austin, Texas. 20 p. Available at: http://www.sustainablebiodieselalliance.com/BPS%20V.1.pdf; 2008.
[187] ETI. The ETI Base Code. Available at: http://www.ethicaltrade.org/resources/key-eti-resources/eti-base-code; 10 May 2001. Acccess date: 9 November 2009.
[188] SAI. Social Accountability 8000. Available at: http://www.sa-intl.org/_data/n_0001/resources/live/2008StdEnglishFinal.pdf; 2008. Access date: 11 November 2009.
[189] CCBS. Climate, community and biodiversity project design standards, second ed., The Climate, Community and Biodiversity Alliance: USA; 2008.
[190] CEPA. Presentation on 'Low Carbon Fuel Standard: Life Cycle Analysis (LCA) Working Group 1 meeting'. California Environmental Protection Agency and Air Resources Board; 2007.
[191] RTRS. Proposed RTRS approach to control of the supply chain (chain of custody), reference DG4-OUT-03-ENG. The RTRS Principles, Criteria and Verification Working Group (DG) as an output of the fourth meeting on 10-13 October 2008, Roundtable on Responsible Soy; 2008.
[192] Senter Novem. Ministeriële regeling dubbeltelling betere biobrandstoffen. Available at: http://www.senternovem.nl/gave/dubbeltelling/index.asp#4; 2009.